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FEATURES

Montana's Bountiful Treasures 12
Part I: Hunting gemstones in Gold West Country
by Kenneth H. Rohn

Crystal Growth 20
Mineral shapes make collecting a challenge
by Bob Jones

Roadside Panning Sites in Texas 34
Part I: 14 sites in six counties
by David and Clois Walker

The Frugal Collector:
The Molybdates and Tungstates 40
A small, but attractive, collectible group
by Bob Jones

Rock & Gem Kids 48
Information and activities for kids
by Steve Decker

Paleontologists for a Day 64
You, too, can dig for dinosaurs!
by Lori Lamb

The Beryl Family 80
A rainbow of related gemstones
by Kenneth H. Rohn

Collecting in Western Oregon 88
A variety of gems in a variety of outdoor settings
by Curtis L. Handy

The Uravan Mineral Belt 96
Renewed mining means more collector specimens
by Steve Voynick

FIELD TRIP

Reading Banks Bombshells 28
A family-friendly field trip in Pennsylvania
by Robert Beard

REGULAR COLUMNS

Craftsman of the Month 6
Show Dates 8
Shop Talk 18
Off the Dop 63
Rock Science 74
Lapidary Lore and More 76
Picks & Pans 86
Many Facets 94
Subscriber Service Information 99
On the Rocks 104

ON THE COVER

The colorful family of beryl gems includes blue aquamarine, yellow-orange golden beryl, pink morganite, and green emerald. Specimens are from the Crystallarium collection, Los Angeles, California. (Photo by Earl Lewis)

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Montana's Bountiful TREASURES

Part I:
Almandine Garnets, Sapphires, and History

Story and Photos by Kenneth H. Rohn

Some of the high-grade garnet crystals found at the Red Rock Mine are so dense they appear almost black.

Gold was discovered in Grasshopper Creek near the town of Bannack, Montana, on July 18, 1862. On May 26, 1863, two prospectors, Henry Edgar and Bill Fairweather, made a major gold strike a quarter-mile south of where Virginia City lies today, in Alder Gulch. Virginia City began to grow and gained prominence in a very short time span after that last rush, which brought thousands into the area from all over the world. Almost overnight, a city sprang into existence, and in 1865, it became the new capital of Montana Territory, replacing Bannack.

No trip to this area of Montana would be complete without a visit to this historic town and her neighbor, Nevada City, located a few miles away on state Route 287, two very well-preserved gold rush towns. While walking the streets of these historic towns, I had the feeling of stepping back in time to another era, when people used gold dust and nuggets for all monetary transactions.

Although as a rule they worked much harder than we do today, life no doubt was simpler then. Photography was in its infancy, there were no telephones, cell phones, computers, automobiles, airplanes, radios, televisions, or other conveniences we take so much for granted. Transportation was by shank's mare, horseback, horse-drawn carriage, and stagecoach over roads that were mere trails. Much later, railroads helped speed up travel to western destinations.

Most citizens in the 19th century West were suspicious of paper money. Gold and, of course, silver were the monetary mainstays of the time. Coinage of any kind, particularly gold, was a scarce commodity. Gold dust, however, was readily accepted. One medium of exchange was a "pinch" of dust for merchandise purchased. Some emporiums hired men with big hands, so the pinch taken out of the gold poke was accordingly more substantial. How much gold dust was lost between the cracks of those wooden floors, and possibly still rests there today, is anybody's guess. I thought of these things as I walked the boardwalks and studied the history that rested silently behind the plate glass windows of business buildings on Wallace Street, many of which had closed shop long ago.

This 34-pound garnet boulder measures 10 inches by 8 inches by 8 inches and is studded with hundreds of garnet crystals of all sizes.

Several anthills on the mountain slope at the Ruby Garnet property are covered with heavy layers of garnet crystals.

I was visiting these towns as the guest of Travel Montana and Gold West Country. Gold West Country is that area of vacation land that encompasses a good portion of the southwestern part of Montana, including, among other important cities, Helena, Butte, Anaconda, and Deer Lodge. It's nestled between Russell and Yellowstone Countries to the east and Glacier Country to the west.

My itinerary began at Nevada City, in the southwest corner of Montana, and I proceeded from there on some very educational, exciting and productive adventures. I would soon be screening and washing my own beautiful almandine garnets, and later I would have a personally guided tour of a commercial garnet mine and processing operation.

It was a warm summer evening when I arrived at Nevada City and Just An Experience Bed & Breakfast, where I stayed for two nights while exploring and sightseeing in Nevada City and Virginia City. I was assigned a rustic log cabin, shaded by old cottonwoods, behind the main lodge. It has a loft bedroom besides the main one on the ground floor where I slept, and a huge bearskin hanging on one wall. Despite the fact that it's a log cabin, with the well-preserved log walls revealed, it has all the amenities of a modern abode and is quite comfortable.

I was served a delicious breakfast each morning in the main lodge and visited with other guests and the charming owners, Carma and John. Carma is an excellent cook and the food was out of this world. They also own Alder Gulch Gold, across the street from the B&B. I wanted to try my hand at gold panning at their establishment, but they were closed the afternoon I decided to visit. My busy schedule never allowed me the opportunity to return.

In the old days, "Gold!" was on everyone's lips, and the economy of these communities relied on the toil and sweat of those miners who produced this often elusive and precious commodity. However, gold was taken out of the ground at Alder Gulch numbering in the hundreds of thousands of ounces. Gold that sold for slightly over $16 per ounce in 1864 now goes for upwards of $400 an ounce.

As you drive from Virginia City to Alder, on state Route 287, the dredge piles are quite prominent, with mounds of boulders appearing as if they were deposited but a short time ago. The last dredge stopped working in Alder Gulch sometime in the mid 1930s.

While strolling along, I stopped at the local ice cream parlor on Main Street in Virginia City and had the best chocolate malt I have ever tasted, made with ice cream made right on site. It was quite an experience.

continued on next page

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Boulders on the Ruby Garnet property contain a high percentage of garnet crystals.

Montana's Bountiful Treasures *from page 13*

I was eager to collect some of those almandine garnets, so one bright morning, I drove on over to the Red Rock Mine & Garnet Gallery, 2½ miles east of the town of Alder on state Route 287. Alder is another town that boomed during the gold rush, almost 150 years ago. Situated in a picturesque valley, it is surrounded by spectacular mountain peaks and has some of the most beautiful scenery to be found anywhere in this country.

I parked my camper in the ample parking lot and met Steven Cox, owner of Red Rock Mine. He took time out from his busy schedule to show me around and make me feel at home. Like most Montanans, when I told him why I was there, he welcomed me as he would an old friend.

Visitors can use a portable screen to sift garnet-bearing gravel at the Red Rock Mine and Gallery.

Steven's mine is actually across state Route 287 from his place of business. He has loads of garnet-bearing gravel dumped in a pile on the premises, and customers are encouraged to dig and screen the dirt for gemstones. The mine material is just as nature left it; it has simply been hauled across the road and deposited in a convenient pile. This gravel is so rich in gemstones it's almost a certainty that you will find a satisfying amount of garnets before you leave. If you don't, Steven has a wonderful selection of garnet crystals and jewelry to choose from in his gallery.

Tools and screening equipment are furnished for our convenience at the gallery. Steven recommends that, if you intend to spend the day digging, you wear a hat to shade you from the hot sun, a pair of work gloves, and work shoes or shoes with some support, and take along a lunch with plenty of liquids to prevent dehydration.

Steven and a friend demonstrated his method of recovering those deep-red beauties for me. His portable screen (available to customers) reduces the material to a manageable size, and the finer screened material is placed in a bucket and carried over to the washing tub. It's then washed with exactly the same system that is used for sapphires. Two screens about 14 inches square are employed. One is approximately ½-inch mesh and the other is ⅛-inch. The loaded screens are nestled together and washed in the tub. When rather clean, the larger-than-½-inch material is carefully inspected for larger gemstones, then discarded. The larger-than-⅛-inch material is further washed, and the lower screen is shaken underwater until all the heavy material settles to the bottom. After a good washing, a foam cushion is placed over the top of the ⅛-inch screen, and it is carefully flipped over onto the worktable. If done correctly, the garnets, which are heavier than the gravel, will be resting right on top after the screen is carefully removed. Then you only need a sharp eye and a pair of tweezers to remove the gemstones before they sink out of sight. When the sunlight hits those deep red garnets, you can't miss them. They stand out like the proverbial sore thumb.

Almandine garnet ($Fe_3Al_2Si_3O_{12}$), a member of a large family of gemstones, can be anywhere from a red-brown color to several degrees and intensities of wine red. (See "Garnets: Six Species, Many Variations," May 2004 *Rock & Gem*.) Some are very dark red, almost opaque. Others are so dense that they appear black. The majority of stones found in any deposit have inclusions, fractures, and other imperfections, but the gem-quality ones are usually outstanding. At the Red Rock Mine, a good percentage of gem-quality stones can be found.

Almandine garnets form in dodecahedrons, crystals with 12 faces, but they are most often found as rounded pebbles or fragments of crystals due to erosion and the harsh environment. The extreme pressure exerted during the formation of this metamorphic-induced gemstone has caused considerable fracturing in a great number of garnets.

Almandine is much more plentiful than all the other members of this family, and during the gold rush days, miners were constantly plagued by these heavy crystals, which clogged the riffles in their sluice boxes and rockers. The garnets, with no intrinsic value at the time, were discarded as a nuisance.

I did rather well during my stay at the Red Rock Mine, and found several very good, rounded and water-worn garnets. At least four will make exquisite gemstones when cut and faceted. The largest one may even top 3 carats when fashioned into a round stone. They are a beautiful wine color and appear flawless under my eye loupe.

It was late afternoon when I said good-bye to Steven and returned to my cabin in Nevada City. It had been a long day, but a most enjoyable and fruitful one. In the morning, I would strike out on another adventure, visiting a commercial garnet operation.

The Ruby Garnet Commercial Mine, owned and operated by Cominco American Inc., is located in Alder, Montana, a short distance west of the Red Rock Mine. There, I met Hart Baltis, geologist and CEO of the company, at his office. One of the great advantages of his company's operation is that the land is being reclaimed after mining, making it appear as it originally did before the gold dredges went through so long ago.

I was given a grand tour of the property. Much of the time, Hart and I struck out cross-country in his high-clearance SUV, as he showed me many of their accomplishments. A company brochure states, "At the turn of the century, gold seeking dredges deposited fine sand containing garnet on bedrock, and piled coarse tailing on top. Ruby is one of the cleanest, most environmentally sound operations in the world. After mining, instead of barren rock piles, the site will once again contain open meadows and wetlands, providing habitat for local and migratory birds and animals." After witnessing the operation close-up, I can say the company is doing just that, and progressing rapidly toward its goal.

continued on page 16

Montana's Bountiful Treasures *from page 14*

After driving cross-country for several minutes, Hart stopped at the mine pit. I couldn't believe my eyes. I was walking on a bed of wine-red stones so heavily concentrated that I could have easily scooped up several handfuls of gemstones anywhere in the area. The mine cut glistened with uncountable almandine garnets of all sizes, from tiny pinheads to some that were ½ inch in diameter. The concentration of garnet, as opposed to ordinary gravel, was overwhelming. I mentioned to Hart that, if his company should ever decide to let collectors in for a fee, it would be an outstanding collecting site. He simply smiled in return.

We then struck out on foot up the mountainside. Of course, being at a much higher altitude than I'm accustomed to, I soon found myself gasping for air as I attempted to keep up. We stopped at an area on the mountainside that was still in its natural state. Everywhere I looked, I saw garnets exposed on the surface. Several anthills contained a solid layer of garnets glistening in the sunlight. Some areas were literally covered with conglomerates containing as much as 90 percent pure garnet and weighing several pounds.

Hart pointed to one beautiful conglomerate boulder as we made our way back down to the SUV. As a passing comment, I said I would love to have that beauty on display in my front yard. Hart picked it up, put it on his shoulder, and proceeded down the slope. I told him that he didn't have to do that, but he only said it was mine and continued on down the mountain. That stone is 10 inches by 8 inches by 8 inches, is studded with hundreds of garnets, and probably contains 75 percent garnet throughout. It weighs 34 pounds. It's beautiful.

It was approaching early afternoon when Hart drove to the plant. Although there wasn't time to inspect the main plant building, I did see huge containers of processed garnet in the warehouse, ready for shipment.

Cominco's Alder operation produces several sizes of garnet, from very fine to coarse. The product is used as an abrasive for a number of applications in several gradients, in the new water jet machines, and for filtration. The finished product contains less than 1 percent silica and is acid insoluble. It's also very clean and free of clay. They ship the product by truck and/or rail in bags weighing 50, 100 and 4,000 pounds and in bulk.

One very important thing about Ruby Garnet abrasives and filtration products is that they are environmentally sound. In other words, the media produced by Ruby Garnet poses no threat to our ecosystem whatsoever.

The bright sun was past its zenith when Hart and I parted company. He was off to a meeting, and I drove on over to Butte to lunch with Sarah Bannon, Executive Director of Gold West Country, at the Red Lion Restaurant. Sarah had reserved seats for us on the Trolley, and we had a grand 90-minute tour of the bustling city of Butte. It was a windy and cool afternoon, and I found myself shivering in short sleeves in the open-air bus as we saw the sights. I made a joking remark that I'm from Minnesota and can take the cold, which was greeted with laughter from the others nearby.

I said good-bye to Sarah and was on my way to the city of Boulder via Interstate 15 for a get-together with Donnie Sexton, Staff Photographer/ Publicity Manager for Travel Montana. We were to visit a radon mine deep underground. I would also go on a packhorse trip into the Sapphire Mountains southeast of Missoula, in beautiful Glacier Country, spending four wonderful days camping in the mountains, and digging for gem-quality sapphires at a private claim. But that will have to wait till the next segment of my story.

The floor of this Montana mountain meadow is red with garnet crystals.

Shop Talk

William A. Kappele

Coming Unglued

With all of the new adhesives on the market, we can be certain that our stones will not fall out of their mountings, caps will not fall off our doublets, and all of the other things we stick together will stay stuck together. And this latter feature is the subject of this month's column.

Let's suppose that you have a stone that you want to remove from a setting (a pin, pendant, ring, etc.). Before picking up the hammer and chisel, there are several things you will need to know and some decisions you will need to make. First of all, do you want to save both the stone and the setting? Second, do you know what type of adhesive was used? Third, if you want to save the stone, is it sensitive to heat or cold? If it is an opal, is it capped?

If you have answered all of those questions and have decided to try removing the stone, just remember that the procedure is always a gamble. The first method you try should be the least destructive one. If your stone is not heat sensitive, that would be either heat or cold. Put your piece in a small frying pan; I bought one in the dime store for a dollar or so that I use for just such things. Wear suitable gloves to protect your hands and turn the kitchen stove on low heat. Using the tip of an X-acto knife or a dental pick, pry very lightly between the stone and the setting. Gradually increase the heat until the stone pops out or it becomes obvious that it isn't going to. If the heat method failed, you can put the piece in your freezer overnight and then pry with the dental pick or knife to see if it will release.

If neither of these methods worked, you should try one of the debonders. If your stone is a doublet or triplet, a debonder is a real risk, since it may well remove the stone from the setting and separate the cap and backing at the same time. If you have a very nice stone of this type, you might want to use the last method I'm going to mention.

If you know the type of adhesive that was used to set the stone, you're ahead of the game. Duco cement, a glue that has been around since time

began and is still sold in hardware stores today, is rather easily removed with acetone. Cyanoacrylates (super glue, Krazy glue, etc.) have achieved urban legend status due to the rumors that if you stick your fingers together with them, only surgery will separate the digits. Actually, running water will do the job. Debonders are also available at almost any store that sells the glue, so have a tube handy just in case.

The real bear of adhesives when it comes to debonding is epoxy. There are industrial chemicals that will soften cured epoxies, but they are really nasty and not the kind of thing you want around the house or shop. There is one chemical called Attack, which will soften epoxy so that you can remove a stone, but it is pretty strong stuff, too. You'll need to follow the warnings on the can to the letter. This stuff is carried by many of *Rock & Gem*'s advertisers. Actually, epoxy is usually rather easy to remove with the heat method, so if you know your stone is epoxied on, try heat first.

Finally, you can use the ultimate method. If you have something like a precious opal and a setting that you can sacrifice, just cut and grind away the setting, and vice versa if the setting is what you want to keep.

Too bad we can't just hit the Undo key! Happy ungluing!

Please feel free to contact me if you have a suggestion or comment about this or any of my Shop Talk columns. My e-mail is quappelle@cox.net, or write to me at 25231 Pericia Dr., Mission Viejo, CA 92691.

CRYSTAL GROWTH

The Variety of Habits Adds Interest to Collecting

Story and Photos by Bob Jones

Admiration of the beauty of mineral crystals is universal. People who have never seen mineral crystals and wander into a museum mineral gallery marvel at what they see. Some even wonder aloud, "How do they make those things?" Such visitors find it hard to believe that these objects of geometric marvel are natural.

If every crystal developed in one of the standard six crystal systems, the study of mineral crystals would be enormously simplified. Such simplification might also be too predictable for the mineral collector. If crystals lacked the great variety and uniqueness we see, a collector's life and mineral collection would be much less challenging and interesting.

Fortunately, crystals within almost any mineral species can and do vary in their habits. This is due to either the peculiarities of a mineral's internal atomic structure, called a crystal lattice structure, or any one of several environmental influences, including temperature, pressure, and saturation of the growth solution.

Think about this: Cuprite forms in the isometric or cubic system. In its simplest form, it occurs as perfect equidimensional cubes. If that were the only form it took, we sure would be missing out on some terrific specimens. And what if every quartz crystal was a simple hexagonal prism, nicely terminated and just like every other crystal from every other deposit? I hate to use the term "boring," but let's face it, what makes mineral species so exciting and challenging is the variety of crystal habits we seek, collect, study, display and thoroughly enjoy!

COLLECTOR'S EDGE SPECIMEN

This lovely pyromorphite from Les Farges, France, shows typical hoppering.

A later solution of calcite crystallized around copper in this oddity from Michigan's copper mines.

Cuprite, for example, is much more exciting when it occurs as octahedrons or even more complex dodecahedrons. These are often a reflection of the environment in which the cuprite forms. Cuprite really gets exciting when it occurs as brilliant red or orange acicular crystals that look like a tangled clump. These are actually perfectly organized crystals that simply grew faster in one direction.

As nice as a simple hexagonal prism is, quartz is a lot more exciting when it is sceptered, twisted, color zoned, or in a solid banded agate full of exciting colors. Where would the lapidary world be without the many varieties of quartz?

Normally, manganese oxide minerals form in rather ordinary—and some think unexciting—black crystals. But allow manganese oxide to crystallize in a still-forming chalcedony agate or invade a crack or seam in the agate, and the resulting black crystal growth is a branching, plantlike, dendritic feature that a lapidary can turn into a lovely gem.

There are countless gems in use today that feature dendritic (some say "moss" or "scenic") agate. Arizona's lovely red, yellow and violet petrified wood is further enhanced by manganese dendrites that seem to be ghostly images of long-dead trees. Such dendritic growth of a mineral within another mineral turns something ordinary into the extraordinary.

So what accounts for things like dendrites, scepters, hourglass images, hoppered, skeletal, phantom, and color zoned crystals? Crystals form because of a basic force of attraction that exists between the atoms or molecules of that mineral. This bonding is what keeps gold atoms together even when you pound the mineral with a hammer. When gold atoms are randomly separated in a solution, they will still be gradually attracted to each other more readily than they will attach to any other elemental atom in the mix. This is the

result of what we call nuclei, small clusters of atoms that can start the growth of crystalline gold. The same is true of molecular compounds in solution.

Electrical attraction is the basic key to molecular growth. Each atom of a given substance accommodates the electrons of a compatible atom, and they bond to form a molecule. Once bonded, these electrons are not fixed, but keep shifting back and forth, forming a locking bond. The result is crystal growth and an identifiable mineral.

When a few random atoms of the same element occur in a melt or solution or even in a vapor, they cling to each other. This forms the nucleus, a critical component for the formation of a crystal. These nuclei gather and break, gather and break, but when conditions like temperature, pressure and solubility are just right, one nucleus joins with others. A crystal has begun to grow.

As a crystal grows, the electrical charges may not be equal on all its surfaces. The electrical force of attraction can be stronger in one area than another. That encourages greater growth in that area. The result is a departure from the norm. In most cases, the electrical charges within the growth area are equal, or nearly so, and a normal crystal growth cycle carries on.

To understand the different habits that we see in crystals—for instance, quartz with its twins, scepters, skeletal crystals and the like—we need a little inside information. Inside the crystal, that is.

The basic structure of a crystal is a lattice made up of the atoms of that mineral species. In quartz, silicon and oxygen atoms form the lattice structure. Certain parts of that lattice are more electrically active than others. The most electrically active areas in quartz are along the edges of a crystal, where side faces meet. The crystal faces in between are less electrically active. In other minerals, the developing termination may be more active. Even the solution in which a crystal is growing can have areas of greater or lesser charge, which may complement areas of the developing crystal. Keep this in mind as I describe minerals that we call dendritic, skeletal, hoppered, sceptered, and the like.

KRISTALLE SPECIMEN

Restricted in a narrow quartz seam, this gold could only crystallize in two directions.

Dendritic minerals are fairly common. Cuprite, pyrite, millerite, manganese oxides, byssolite, gold, silver, copper, and any of the "hairy" minerals fit this category and develop in much the same way. They grow dramatically in one direction and more slowly, sometimes hardly at all, in others.

Take cuprite as an example. Normally, as its copper oxide nucleus develops in a copper-rich solution, it takes on a cubic habit. As the solution cools, this process is accelerated because there is less and less space between the molecules of the dissolving liquid. This increases the concentration of the copper oxide, forcing it to leave the solution and take up less space as a solid. If the solution is a little more electrically charged around the termination of the growing crystal, this encourages an interaction between the growing crystal and the solution. The copper oxide in the solution can also be attracted toward one face or edge of the developing crystal, and growth will be more rapid there. Because of the lattice structure of the cuprite, the termination end tends to be slightly stronger electrically, and this will increase the growth to that section as compared to the side faces. One result can be a discrete, but distorted or elongated, crystal. But if the growth is exceedingly rapid in that one direction, a dendritic or acicular cuprite crystal evolves. This hairlike form of cuprite is called chalcothrichite. "Chalco-" means "copper," and "-thrich" means "hair."

The same is true of other acicular species like millerite and the metal elements gold and silver. In copper, gold and silver, the result isn't hairlike, but arborescent. As these metals tend to develop in existing rock structures, which can be heavily fractured, it is unusual for two-dimensional, branchlike crystals to develop.

Aside from the outward hairy appearance of acicular minerals, including chalcotrichite, there is yet another external difference: color. Normal cubic or octahedral crystals of cuprite are a deep, dark red. After all, light can only penetrate a dense crystal surface so far. Density inhibits a lot of the light from escaping to your eye. This negative effect determines how bright the crystal's visible color is. By developing a dendrite, the crystal has, in effect, created a thin edge that can transmit light more readily. Acicular or dendritic cuprite shows a brilliant red color. Likewise, azurite crystals are commonly dark blue to nearly black. But when azurite forms as velvety, hairlike crusts, its color is a lovely light blue. Massive malachite may show contrasting dark- and light-green shades; the lighter-colored bands are a bit less dense than the darker bands.

continued on next page

EVAN JONES COLLECTION

Rapid growth in malachite frequently causes needle crystals to develop.

This hairy-looking mass of cuprite, variety chalcotrichite, is from Cornwall, England.

Crystal Growth *from page 21*

Another common crystal-growth oddity is hoppering. Instead of developing with a predictable termination, the edges of the termination grow much more rapidly. The resulting crystal has a castellated termination that is no longer flat or smooth. It looks as if it's been drilled or depressed in the center.

Among the many minerals that develop a hoppered habit are mimetite, a lead arsenate; pyromorphite, a lead phosphate; and vanadinite, a lead vanadate. It's interesting that these three species are all lead minerals.

Hoppering results from one of two circumstances. First, as a crystal develops, some defect may occur on the termination face, so the incoming molecules of the mineral have trouble attaching uniformly and they tend to load up along the edges of the termination. Second, and much more commonly, the force of electrical attraction is stronger on the edge of a crystal than in the center of a face, and the crystal grows more rapidly along the edge.

The same explanation can be applied to the skeletal crystals so commonly seen in quartz. Where crystal faces meet, the force of attraction is slightly stronger, so molecules build up along those edges, while the prism faces grow more slowly. This does not happen in every quartz crystal because either the supporting solution or the developing crystal itself is electrically balanced, or nearly so.

Some crystals show a skeletal form due to etching but that is an outside influence, acidic solutions attacking the quartz.

Interference with crystal growth is a common problem in nature, where no mineral-growing solution is pure. The variety of dissolved elements or compounds present in a solution can play a role in any crystal's ability to grow. The obvious example of this, and one that produces delightfully interesting display specimens, is phantoming. A phantom crystal shows at least two, and more often three or more, stages or phases of crystal growth. Normal crystal growth is interrupted when the solution runs out of the crystallizing element or when its environmental circumstances change. The growth of that crystal stops, but the original solution may still carry other mineral matter that crystallizes at a different temperature than the first. Small crystals of a second mineral may develop on the faces of the original crystal. Later, the solution may be rejuvenated by an infusion of mineral-rich solution, or cool rapidly, causing continued growth of the original species. Because

The phantom in this Brazilian quartz is due to included clay.

the original crystal is now thinly shrouded by another mineral, it is invisible as a phantom within the final crystal.

Phantoms can also form when a second solution carrying yet another mineral in quantity is introduced. If its internal structure is compatible, the new mineral may overlay that first crystal, forming a phantom. For this reason, we see calcite images in quartz and vice versa. Some pegmatite deposits in Brazil have yielded superb quartz phantoms repeatedly sequenced with a clayey material; the final crystal may show a half-dozen or more phantoms.

One of the more popular forms of quartz is the scepter. Quartz scepters are certainly decorative and can even be varied in color. The crystal usually starts out as a single more-or-less regular, six-sided, slender prism. Then another quartz crystal, usually fatter and sometimes of a different shade or color, develops atop the termination of the original crystal. There is obvious cause and effect here. The electrical forces near the termination of the first crystal attract that second crystal to it, and growth commences. This is possible because the internal lattice structures of the two quartzes are virtually the same.

I like the theory proposed by the late Dr. John Sinkankas. He suggested that the original crystal may well be nearly buried in mud or clay, with just the point of the crystal protruding. If that's the case, then a second quartz-bearing solution could very well come along and cause the growth of the sec-

ond crystal atop the termination of the half buried crystal It has been shown that the side faces of a quartz crystal tend to be quite stable and are lower in energy than the termination end So any newly forming crystal might well find a more friendly location at the termination end of the original quartz

One of the exciting things about quartz scepters is that the second crystal perched atop the first may be smoky or amethyst, while the original is a classic, colorless rock crystal The explanation of the difference in color of the host crystal and its scepter starts with the understanding that there are two different solutions involved The second solution may be slightly richer in aluminum or iron Each of those common impurities can substitute for silicon atoms in the structure and cause color centers, areas within the structure where electron movement affects the light that goes into and comes out of the crystal If the scepter is amethyst, its solution may well have contained a slight trace of some radioactive material. This creates a very unusual electron configuration within the quartz, which causes the violet color If a smoky quartz sits atop the primary colorless crystal, the color is from a disturbed electron arrangement due to the presence of iron or aluminum atoms.

Pegmatite deposits seem to produce a variety of odd-growth crystals Complex-looking clusters of quartz crystals in more-or-less parallel arrangement and sometimes weighing many pounds have been mined out Such clusters are examples of parallel overgrowths The scientific name for this is epitaxial growth. The pegmatites of Brazil and North Carolina have produced these overgrowths in quantity, those from North Carolina are often a lovely amethyst, while Brazilian parallel growth quartzes are often smoky to clear

Parallel growth develops on the surface of a complete crystal The new faces do not develop smoothly or equally due to factors such as electrical forces and direction of growth (in a spiral versus a flatter, more even growth) Uneven growth of various crystal faces is so common, we name the resulting defects hillocks, pits, striations, etc We use them as identifying features on many crystals Hillocks are particularly prone to causing the development of parallel overgrowths.

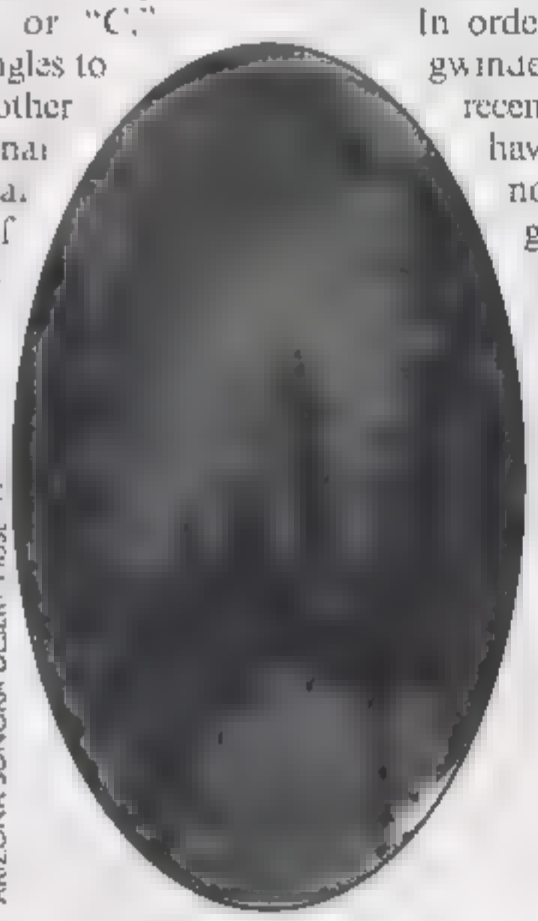
The hillocks tend to attract additional crystal nuclei, which may develop much faster than the host crystal They are able to align their internal crystal lattice structure with that of the host crystal The result is the birth of a second discrete crystal This can happen again and again along the prism faces of the same host crystal So you end up with a dozen or more crystals, usually all doubly terminated, growing side by side, parallel to each other This parallel growth habit creates a most attractive crystal grouping

continued on next page

These crystals grow in the same direction because of the internal atomic structure of the host crystal and those of the newcomers. The molecules that make up that original crystal have arranged themselves in a very orderly geometric pattern, tetrahedrons in a spiral, or helix, form, oriented around several axes. The spiral curls around a vertical, or "C," axis. Protruding at right angles to this "C" axis are three other axes. The external hexagonal shape of a quartz crystal reflects the positioning of the molecules that have coordinated around the three axes. Each of these three axes becomes the center for two faces on opposite sides of the crystal. This results in the six faces for a quartz crystal.

What does this have to do with parallel growth? As the nuclei of those secondary growth crystals attach themselves to the primary crystal faces, they must, because of the forces involved, align their atomic lattice structures with that of the host crystal. That, in turn, is shown by the external orderliness we see as a series of smaller crystals aligned on a larger, older crystal, and these we name parallel overgrowths.

We can point to hoppered crystals, parallel growth, and others as examples of electrical forces at work. Yet, perhaps the most obvious example of these forces can be seen in crystals that exhibit selective incrustation. This term refers to those crystals that have distinctly different crystal face conditions. Calcite, a mineral with six faces, can be brilliantly lustrous on three alternating faces and dull or coated on the other three alternating faces. This is the result of differences in electrical condition. Often, one set of three faces will attract minor amounts of a different mineral or impurity, which tends to dull those three faces, but not the other three. Quartz can show this, as well, on its six termination faces, whereby each alternating face is coated by a second mineral. Such apparent oddities are best explained by suggesting that second mineral or dulling of alternating faces is due directly to the electrical attraction between those selected faces of the host crystal and the attaching impurity.



ARIZONA SONORA DESERT MUSEUM

Restricted growth area caused manganese oxide to form branching crystals in Arizona petrified wood.

Everyone enjoys seeing the smoky quartz crystals from Switzerland, called gwindels, or twisted crystals. They certainly seem unusual and odd, but they are not as odd as you might think. They are not an unusual form of quartz, but have to do with the positioning of what might otherwise be normal quartz crystals in relation to each other.

In order to explain these Swiss gwindels, and those more recently found in Russia, you have to compare them to a normal quartz crystal. In a gwindel crystal, the sharp boundary that separates any two contiguous faces of the crystal isn't exactly straight. And the faces aren't as flat as you first thought. Instead, they tend to curve or twist slightly, so their point of contact, that supposedly straight edge you are looking at, also curves slightly. How come? Is that a defect in all quartzes? No! It is the result of the internal spiraling arrangement of those silica tetrahedrons. When they stack, they simply cannot stack evenly, each successive crystal is slightly offset, causing growth in a curving or spiral form. They are simply the external expression of the internal spiral of molecules.

Normally, quartz crystals develop with the long, internal "C" axis vertical to the point of attachment. Therefore, most quartzes are nice, slender prismatic, six-sided crystals much longer than they are wide. Gwindels, on the other hand, and for some reason I can not explain, grow on their side prisms. This allows each crystal to be doubly terminated. It also means the terminations are pointing sideways instead of vertically. So, gwindels are composed of a stack of doubly terminated crystals on their sides. Because they orient themselves to the internal lattice structure, which is spiraled, the resulting stack has to be faithful to the laws of crystal growth and stack in perfect order while following that curving pattern. So, the entire stack of crystals, often as many as six, exhibits an exaggerated curving or twisting. And since they share a common axis orientation, they are twinned one to the other. When you hold a gwindel in your hand, you are looking at a stack of individual crystals twinned to each other with terminations off to each side instead of at the vertical top of each crystal. And instead of the crystals being vertically oriented, they end up stacked one on another on their side prisms.

Most collectors are familiar with the classic hourglass gypsum crystals commonly found in Oklahoma. The normal selenite crystal is perfectly formed, terminated and complete, a textbook monoclinic crystal, but enclosed in these crystals is a perfect hourglass shape created by included sand. Just how did that sand get so perfectly arranged during the selenite crystal's growth? First, the selenites are growing in a solution loaded with tiny sand grains that become trapped within the crystal. As selenite develops internally, two distinctly different and opposing atomic arrangements develop. These arrangements are responsible for growth in opposite directions. Sand grains are attracted to them by electrical forces. With each succeeding growth layer, a slightly wider layer of sand attaches, and by the time the crystal is fully formed, two wedge-shaped figures that form the hourglass image have been created.

Color zoning in crystals, which is very pronounced in quartz, is due to any one of several causes. The distribution of impurities is the most important one. As the quartz develops, each successive layer of growth may alternately contain iron and then aluminum impurities, the solution itself may change content depending on conditions. The crystal may still be colorless as it develops. But if the crystal is later irradiated by some nearby radioactive mineral or solution, the effect is dramatic. The iron-rich zone will become a superb violet color, while the aluminum rich layer or zone will turn smoky. In between may be layers of nearly pure silicon dioxide, which remain colorless. The amethyst crystals from North Carolina and from Arizona's Four Peaks Mine commonly produce crystals that are zoned like this.

Impurities in tourmaline crystals also account for the color zoning seen in them. They can range from colorless to pink to red to yellow to gray and so on due to impurities like iron and manganese.

So the unusual and varied habits of crystal growth are due in large part to the selective electrical forces active during crystal growth. Whatever the cause, the results are what make crystallography a most exciting part of the mineralogy scene and the collector hobby. The collector who can study and learn the crystal forms of minerals is not only enriched in knowledge, but adds a wonderfully appealing dimension to collecting itself. ✎

FIELD TRIP

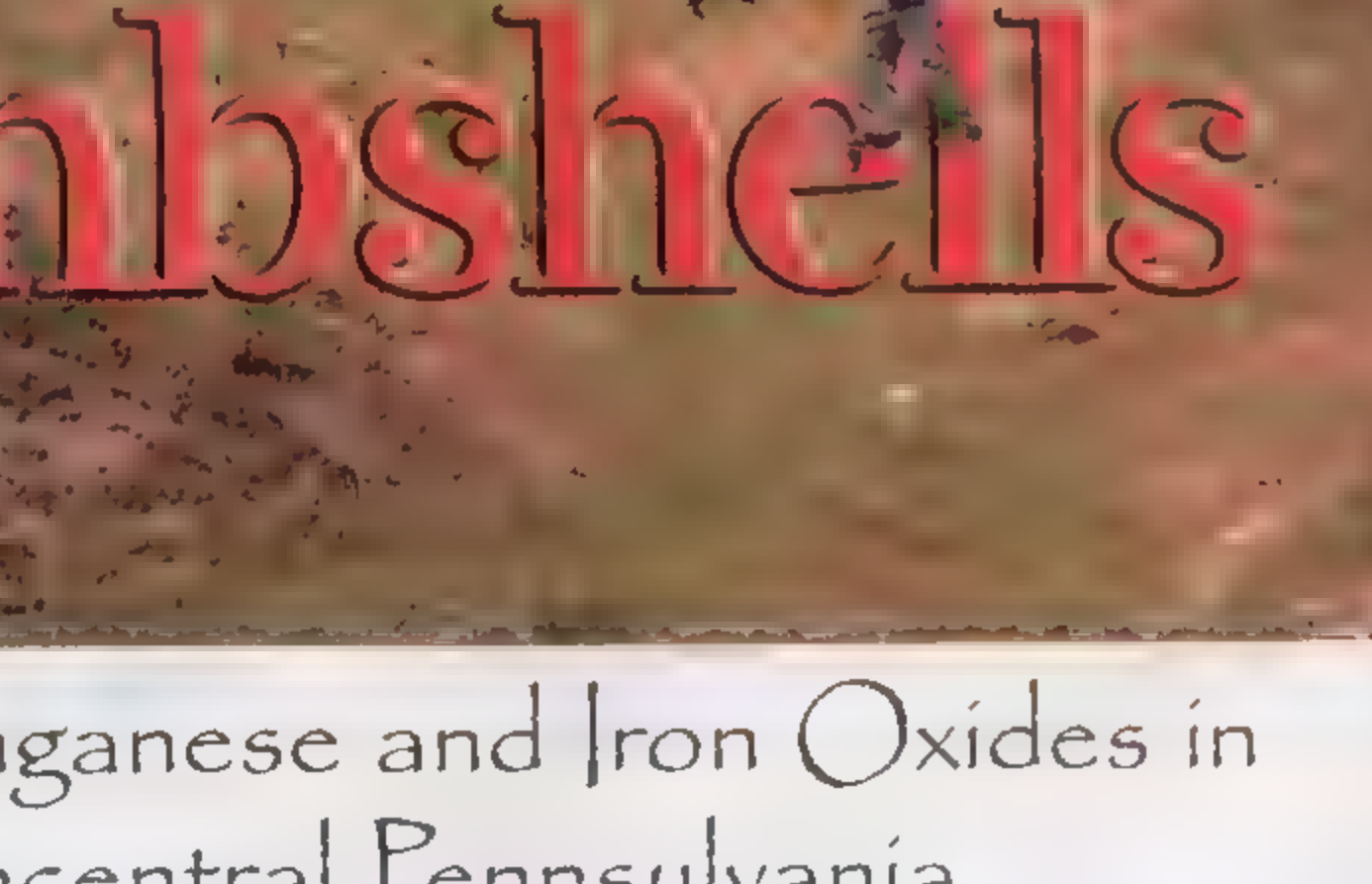
Reading Bombshells

Collect Manganese and Iron Oxides in Southcentral Pennsylvania

Story and Photos by Robert Beard

Geodes are always good rocks for collecting. However, typical geodes are often not locally available. Most collectors think of geodes as rocks filled with brilliant, clear crystals, and unless you are near classic localities like Keokuk, Iowa, or productive road cuts or quarries, it can be difficult to come up with a geode collecting trip on short notice.

I faced this dilemma when my nephew and niece came for a visit to Harrisburg, Pennsylvania, during the summer of 2005. They are from El Paso, Texas, and we always take them and my son and daughter on rock collecting trips when we visit Texas and New Mexico, so we wanted to do some similar trips while they were in the East.



Many of the larger bombshells have interiors coated with light-brown limonite and resemble polished hardwoods.

The cryptomelane often has hard, shiny, steel-gray surfaces that appear polished. Red lepidochrosite is also found at this location

We started our Pennsylvania trips by hiking some of the nearby fossil sites in the Devonian Mahantango Formation, but my nephew asked if we could find geodes to collect. I had to think about that one. In Pennsylvania, we have a tremendous variety of geologic units, but I was not aware of any good collecting localities for geodes with quartz or calcite crystals—at least nothing that we could access easily with an entire family and without steel-toed boots and hard hats. This ruled out quarry trips, and we were also confined to an area within about an hour's driving radius because of our time constraints. No kid likes to sit for several more hours in a car after spending several hours on a plane.

I then remembered that Pennsylvania has some interesting geodelike deposits of manganese oxides and goethite. These are often referred to as "bombshells," because when broken, they resemble fragments of cannonballs. They do not have quartz or calcite crystals, but are black or brown with a bubbly and sometimes shiny appearance on the inside. They also have the huge advantage of being generally easy to find at the collecting sites.

After some thought, I selected the iron-manganese deposit at the Reading Banks in Cumberland County, Pennsylvania, for our bombshell collecting trip. The Reading Banks is a somewhat misleading name, as the deposit is nowhere near Reading, Pennsylvania, and it is also away from any nearby rivers. The Banks are approximately 1.5 miles southeast of the town of Boiling Springs, and about 0.5 mile west of the Appalachian Trail. The site is easily reached from Interstate 81 or state Route 15.

I learned of the Reading Banks deposit from the 1976 version of "Mineral Collecting in Pennsylvania," General Geology Report 33 of the Pennsylvania Geological Survey. A 1969 printing of Report 33 does not describe the Reading Banks deposit. Unfortunately, you can no longer buy either of these books from the state. They are out of print, and it is becoming harder and harder to find copies of them. I bought mine at a mineral show several years ago, and if you find either copy available, you should buy it.

My friends at the Survey have indicated that, since many of the deposits are on private property, the books can no longer be published. My opinion is that this is a bunch of nonsense, as ownership and access changes on a frequent basis, while the deposits stay in the same place. Since my Pennsylvania tax dollars go to promoting tourism, the Survey should put this book back into print to encourage collectors to stay in Pennsylvania and spend their money here. Maryland has a similar publication, "Mines and Minerals of the Washington, D.C. Area" (Educational Series No. 5 of the Maryland Geological Survey), that it continues to print and sell, so why can't the Pennsylvania Survey put its collecting book back into print? At this time, if you cannot find a copy of Bulletin 33 for purchase, your best bet is to visit the Pennsylvania Geological Survey in Middletown, Pennsylvania, to review a copy.

Many of the unwashed bombshells resemble large pieces of wood, but their density and bubbly appearance give them away

Good information on the Reading Banks deposit is provided in "Manganese Minerals of Pennsylvania," by Richard M. Foose, Mineral Resource Report 27 of the Pennsylvania Geological Survey. This book was originally published in 1945 and was reprinted in 1974. Ironically, while the collecting books are out of print, this publication can be purchased at the Pennsylvania State Bookstore in Harrisburg. This bookstore also has many other state geology publications and is well worth a visit if you get the opportunity.

Foose described the Reading Banks deposit in additional detail in "Iron-Manganese Ore Deposit at White Rocks, Cumberland County, Pennsylvania," Bulletin M-26 of the Pennsylvania Geological Survey. White Rocks, which is a very prominent ridge of Antietam Formation quartzite, is about a half mile southeast of the Reading Banks. The two deposits are often discussed together in the literature since they are so close to each other. This bulletin was also published in 1945, however, it is out of print and very difficult to find. The Pennsylvania Geological Survey has a copy available for review, but it cannot be checked out.

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The western side of the Reading Banks is heavily wooded, but previous mining efforts have left several broad pits and cuts in the hillsides.

The Reading Banks were first explored for iron around the time of the Revolutionary War. By 1873, approximately 2,000 tons of ore had been removed, and most was smelted at the Boiling Springs furnace. The ore was reportedly quite satisfactory. The Philadelphia and Reading Coal & Iron Co. began two large operations at the Reading Banks in 1872 and mined ore for about 20 years. Open-cut and underground methods were used. The western open cut, which was then known as the Egg Bank, was about 1,000 feet by 300 feet by 80 feet. The eastern pit, known as the Beidhoover Bank, was a little smaller, but it slumped and filled with water, and was abandoned around 1893.

The company removed about 700,000 tons of ore, and at least some was smelted at Boiling Springs. Unfortunately, as furnace technology improved the ore could no longer be smelted as easily, and the resulting pig iron was "cold short," meaning that it became brittle when cold. This was due to the high manganese content of the deposit, and finally led to shutting down the operation.

The manganese, while it effectively rendered the Reading Banks deposit uneconomical for the iron furnaces, later created additional interest in the area. As World War II approached, it soon became apparent that securing new manganese supplies would be critical for American industry. In the late 1930s, virtually all manganese was imported, and there was a real danger of having supplies cut off.

Manganese is used mainly as a scavenger element in the manufacture of steel. The manganese helps to deoxidize and desulfurize the molten mass of steel. This enables the steel to be used under a greater variety of conditions and increases the ability to work the steel in forging, rolling, and other steel manufacturing processes. Contrary to common belief, relatively little of the manganese used by the steel industry is used for alloy products. Products are not considered manganese alloys unless the manganese content exceeds 1.65 percent. However, when smaller amounts of manganese are used, the steel is still imparted with additional hardness and toughness.

The Boston, Massachusetts, firm of Leghorn and Mitchell began exploration of the area in 1939, and in 1940, 1,500 tons of manganiferous iron ore were stockpiled, and three carloads of ore were shipped to a smelter. In 1943, the U.S. Bureau of Mines completed two exploration drill holes at the Reading Banks, and ore minerals in the clay were located approximately 80 feet below the bottom of the pit. This is apparently detailed in "Investigation of Boiling Springs Manganese-Iron Deposits, Cumberland County, Pennsylvania," U.S. Bureau of Mines Report of Investigations 4436 (1949), but I have not had the opportunity to review this reference.

Despite the sudden interest in manganese, exploration work was soon abandoned, and there has been no activity in the district since the drilling in 1943. The Reading Banks and the other iron mines in the area were soon overtaken by forests and relegated to obscure references in mineralogical databases.

The main manganese mineral at the Reading Banks is cryptomelane. Cryptomelane is one of the commonest of the hard, black manganese oxide minerals, and was formerly referred to as psilomelane. Its new name comes from the Greek words "kryptos," meaning hidden or secret, and "melas," meaning black. Manganese oxides, while generally easy to identify as a group, are notoriously difficult to identify as individual mineral species. Identifying the other individual minerals at the Reading Banks is also difficult, and I have generally found it best to classify the hard, steel-gray, shiny minerals as cryptomelane/manganese oxides and the brown-black minerals as goethite/limonite/iron oxides. In addition to the cryptomelane, other manganese minerals reported at the Reading Banks include pyrolusite, manganite and romanechite. Lepidocrocite, which is a polymorph of goethite, is also reported at the Reading Banks, and may be distinguished from goethite by its red color.

The ores at the Reading Banks occur within the Cambrian-age Tomstown Dolomite, which overlies the Antietam Sandstone, also Cambrian. The ores are interbedded within the clay of the Tomstown Dolomite. The manganese and iron minerals occur in bedded and nodular form, and formed as replacement minerals, impregnation or matrix minerals, and precipitation minerals. All of the minerals are oxides and likely formed as near-surface deposits through the leaching actions of moderately warm, relatively shallow, slightly acidic groundwater. With the exception of the ridges formed by the Antietam Sandstone at White Rocks, the formations are generally poorly exposed in the area.

My wife and I first visited the Reading Banks deposit in the early 1990s. The Reading Banks are on the Mechanicsburg U.S. Geological Survey 7.5-minute topographic quadrangle. The deposits are easy to find on this quadrangle, as they have the name Reading Banks near them. However, this does not clearly specify the location of the banks. The information from General Geology Report 33 shows that the banks are the large depression that has been cut into the north flank of Long Mountain. Using a *Pennsylvania Gazetteer*, published by DeLorme of Yarmouth, Maine, and with some additional information from Mapquest.com, I was able to identify the street that led to the Reading Banks as Criswell Drive. Criswell Drive is also shown in Report 33, but the other references are provided here in the event one cannot get a copy of Report 33.

As with most collecting sites in Pennsylvania, we had to ask permission before entering the area, but we had no trouble obtaining it. The landowner was actually impressed that we asked. She said that, during hunting season, so many deer hunters walked right onto her land without asking that it was nearly impossible to control, and she found this frustrating. Being polite and asking for

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permission prior to entering a site makes a huge difference in the reception you will get from landowners.

When collecting manganese and iron oxides, it is very important to understand what you are looking for. Manganese mineral names include such unflattering terms such as "wad," which describes manganese oxides that contain other metals, and "rat's hair," which is used to describe the velvety, sooty and soft black manganese oxides, which are generally pyrolusite. At the Reading Banks and many of the other manganese-goethite localities in Pennsylvania, the rocks that you are looking for will be dark and somewhat less than attractive at first. However, many of the pieces, especially the cryptomelane, have beautiful botryoidal textures of steel gray and, sometimes, iridescent surfaces that are unlike any other minerals you may have seen before.

The rocks that we found were quite striking. We found numerous pieces of limonite and goethite, but the most unique pieces were the broken "bombshells" lined with botryoidal manganese and iron oxides. The oxides were nearly jet black, and in some cases were quite smooth and glossy, and appeared polished. Many of the pieces with limonite were light to dark brown and resembled pieces of wood. They were easy to find and could be broken with a hammer in a single blow. All the pieces we found were loose, and we did not find any material in outcrop.

Although this was a good site to visit, we did not take a return trip until early July 2005, when we went searching for geodelike rocks with my nephew and niece. We had a large group that included my wife, son (11), and daughter (9), my nephew (12), and niece (10), two sisters-in-law, and my mother-in-law.

Upon arriving at the site, I went to ask permission from the occupant of the house nearest the parking area, and he said no problem. He thought going to the mine to look for rocks was a great thing to do with your family, and he was happy to give permission. I thanked him and we went on our way.

We had two vehicles and were able to easily park both at the trailhead at the southern end of Criswell Road. The road ends in a small circle and there was more than adequate parking. The trailhead starts at a gate, and heads on a steady, slight incline up the mountain. Since it was early July, the area was heavily overgrown, and although the trail was well marked, it did not appear to be used frequently.

We soon saw the first sign of the mine, a sign that read "White Rock, Black Clay Mine" and "Pen Products Co." However, the sign appeared pretty old, and there were no indications that any mining vehicle had used the entrance road in decades. We continued up the trail, and it soon veered to the right. We then came upon a large break in the trees, and a wide-open area with a large bank showed that we were at the site of the Reading Banks. My GPS unit gave coordinates of 40° 08.035 N, 077° 06.582 W, which is in the format of degrees, minutes, and decimal minutes.

Although no mining or serious exploration has occurred here for nearly 60 years, the area has remained open. The banks near the open area have a relatively gentle slope, and the sides are sandy, with no indications of any outcrops. The banks slope to the south, toward Long Mountain and the woods, as opposed to sloping away from Long Mountain, indicating this was likely a very broad mining cut. Almost immediately, we found some heavy chunks of limonite-goethite mineralization. I smashed these with my hammer, but there were no indications of cavities or bombshell ore. They were best described as spongy, ugly brown masses of limonite and goethite.

The kids were content to look around in the sandy zones, and I walked west along the trail. The banks continued to the west, and the sides became heavily wooded and much steeper. I soon found some large pieces that I broke apart, and I was pleased to see that these pieces had cavities inside. I brought the pieces back to the sandy part of the banks to show the kids, and we then went for a hike along the trail to find some more good pieces.

We did not find many more pieces on the trail, but we did find that the banks extended quite a bit to the west. We soon found the trail that returned into the banks. The area appeared to be a gigantic trench that had been taken over by trees. We began to walk back into the trench in an eastward direction to return to the sandy part of the banks. We began to find more good pieces of goethite, and some of these had some intriguing "boxwork" structures in the open spaces between some of the layers.

I soon found several pieces along the north side of the wall. Several of these were hollow and, when broken, formed shapes that were just like the side of an exploded cannonball. Many of the surfaces were black, and some were steel gray. Based on the descriptions from the literature, I assumed that many of the dark black to steel-gray botryoidal surfaces were cryptomelane, while the brown to brown-black minerals were goethite and limonite. Many of the pieces were filled with dirt and needed to be washed.

I later brought the rocks we collected into the sun, where they looked far more interesting. The most spectacular piece was full of hard, shiny, black cryptomelane, and it was iridescent, with a brilliant rainbow sheen. However, it was still quite dusty and it would become even more colorful when it was washed.

I kept most of the rocks intact for breaking open later. Often when we are on a family trip like this, our collecting time is limited, and we are sometimes rushed to finish. This was especially true in this case. Though it was a short hike for the kids and one of my sisters-in-law, it was a little far for my mother-in-law, so my wife and her other sister waited with her closer to the car. When we returned to the car, I took another GPS reading for the parking area. The coordinates were 40° 08.194 W, 077° 06.673 N.

Although our time at the site was very brief, we still found many excellent pieces. It would be useful to further explore the areas described in Pennsylvania Geological Survey's Mineral Resource Report 27, which is easily obtainable, unlike many of the other references on the deposit. Some of the mineralized areas might be further identified with a more systematic and thorough approach. It would also be interesting to see if anything remains of the stockpile of the ore that was mined in 1940. The reference states that only three carloads were removed, so a pretty large pile must remain there unless it was later removed. I am sure that one could find some museum-quality cryptomelane and goethite at the Reading Banks with more diligent searching.

The Reading Banks site makes a good family outing at nearly any time of the year, except during periods of snow cover and during hunting season. To get to the site, take state Route 174 to Leidigh Drive. Follow Leidigh Drive southeast over Yellow Breeches Creek, and turn south onto Criswell Drive. Take Criswell Drive to where it ends at the base of Long Mountain. Don't forget to get permission prior to going on the property. The biggest hazards are going to be poison ivy, ticks, and mosquitoes, but those are all manageable. If you come properly equipped, understand the geology and your target minerals, and are ready to look for some rocks, you may well find some exceptional specimens at this site.

ROADSIDE PANNING SITES IN TEXAS

Part I: Six Counties Provide Ample Opportunities

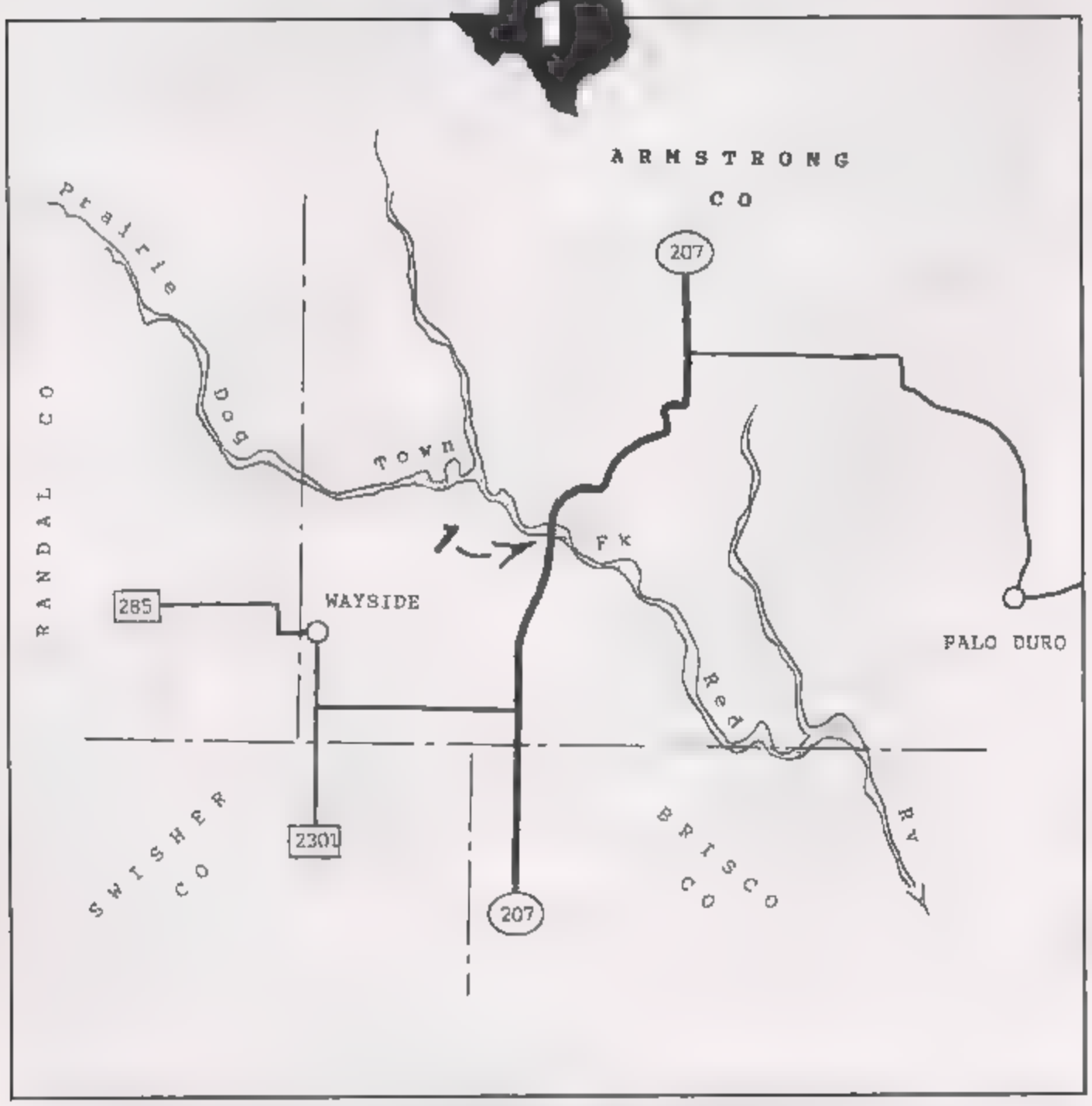
Story and Maps
by David and Clois Walker

This is the first in a series of six articles containing county-by-county maps to suggested panning and screening sites at Texas highway/stream crossings where appreciable finds have been previously reported in vicinity watersheds. The principles of erosion make it likely that minerals and gemstones have been deposited in river gravels, awaiting removal by a rockhound with a pan.

By confining operations to within government-purchased highway rights of way, panners are spared the necessity of locating and obtaining permission from adjoining property owners, including state and national parks and Indian reservations. However, readers run the risk of prosecution if they cross onto private land, whether purposely or inadvertently. In instances where rights of way have merely been leased, other rules may apply. Visitors are urged to inform themselves of possible limitations by calling Rose Willrich at (512) 225-1462 *before* making a trip. The Texas Annual Vacation Guide, as a companionate source of information, is available by calling (800) 888-8839.

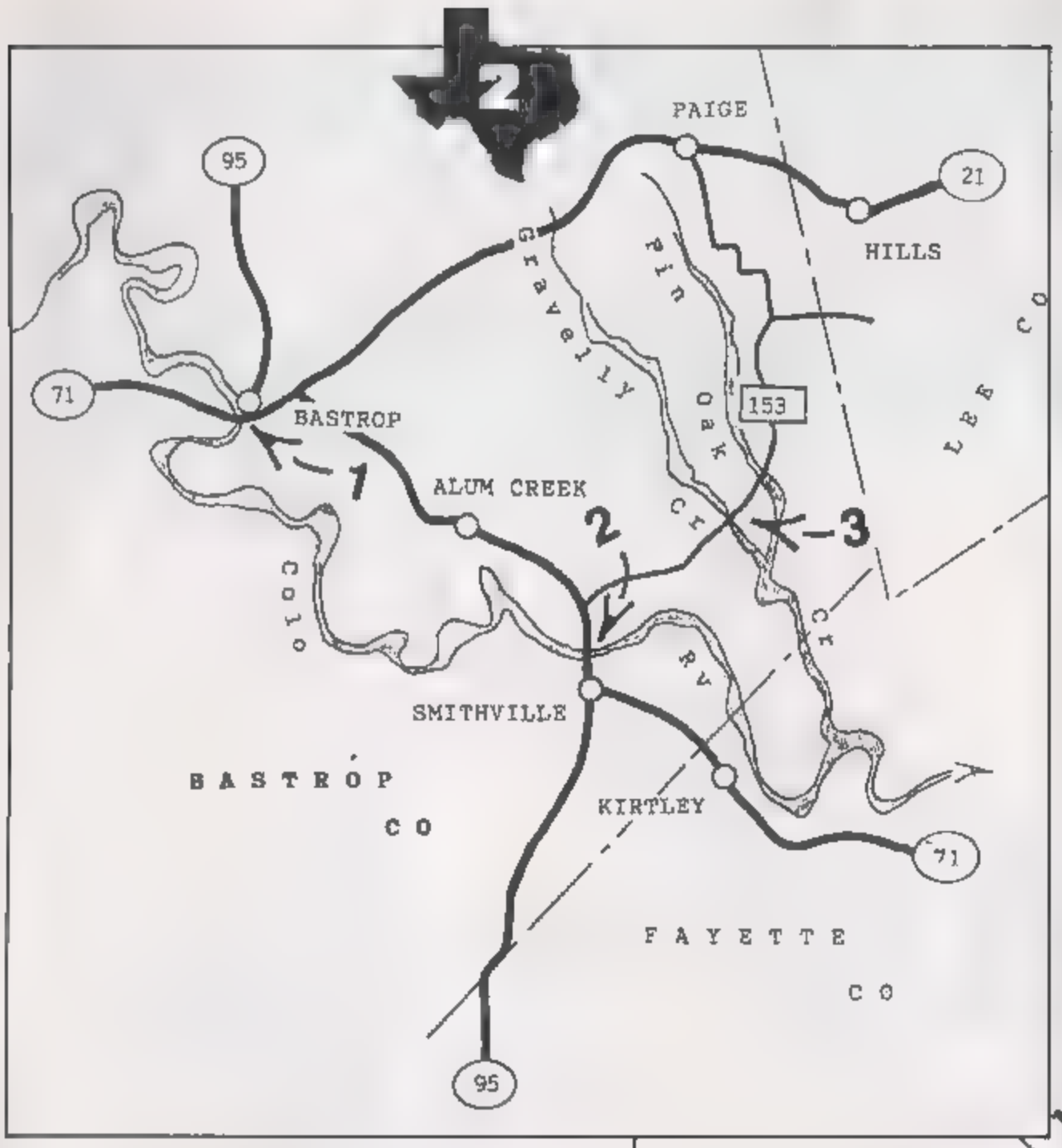
Remember that the government to which these rights of way belong has some regulations of its own. Observe highway safety and environmental standards, such as parking only where designated, and using only a pan and scoop.

The maps provided contain the most up-to-date information available to us, but it is advisable to consult a current state highway or county map when planning an outing, for overall orientation in the field and because highway designations have been known to change.



ARMSTRONG COUNTY
(MAP TX1)

Site 1 **Prairie Dog Town Fork Red River/state Route 207** crossing near **Wayside.**
Vicinity finds indicate moonstone potential

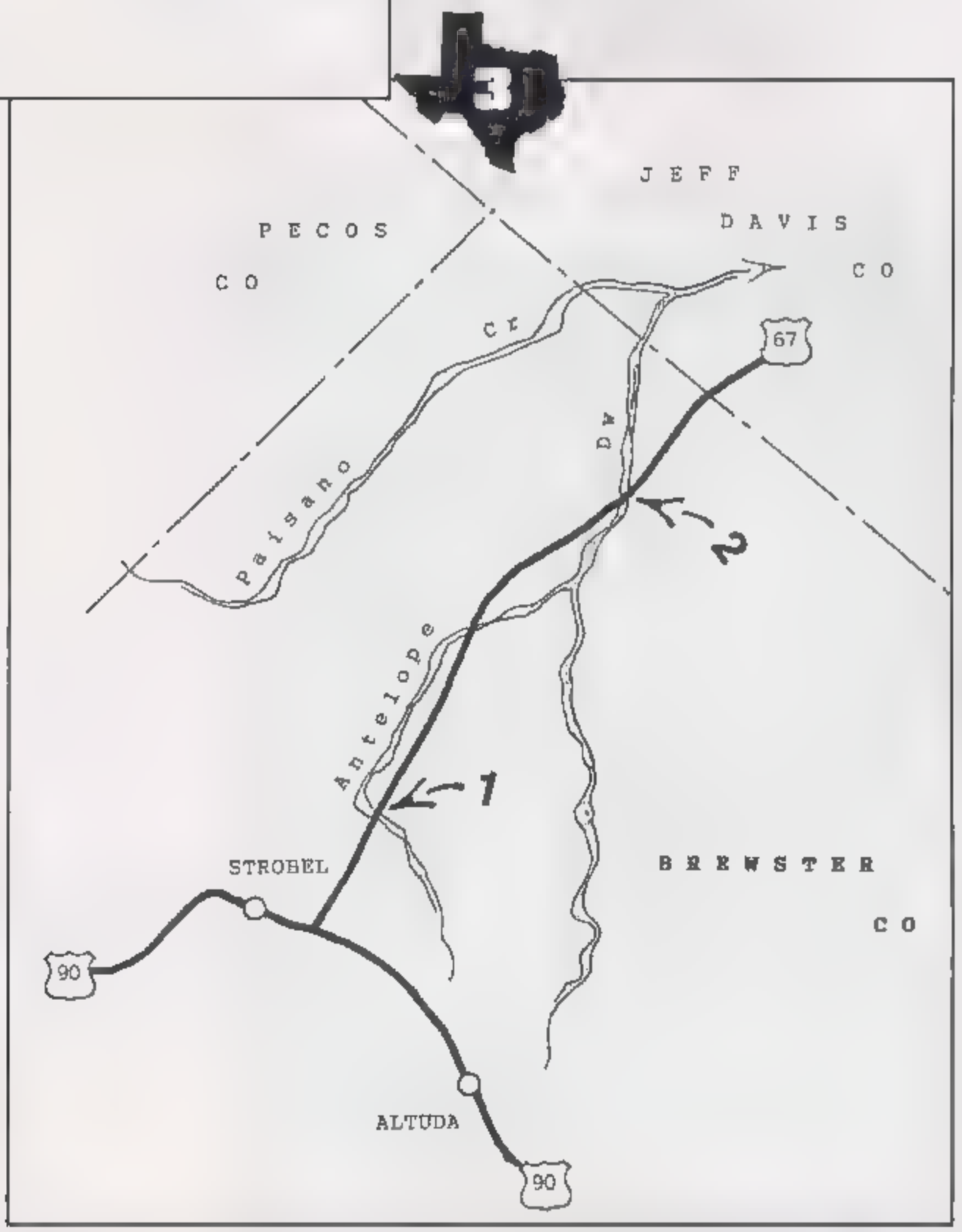


BASTROP COUNTY (MAP TX2)

Site 1 **Colorado River/state Route 71** crossing near **Bastrop.** Vicinity finds include agate and silicified wood

Site 2 **Colorado River/state Route 95** crossing near **Smithville.** Vicinity finds include agate, opalized wood, palm wood, and silicified wood

Site 3 **Gravelly Creek/FMR 153** crossing near **Smithville.** Vicinity finds indicate gold potential



BREWSTER COUNTY (MAPS TX3-6)

Site 1 **Antelope Draw/U.S. Highway 67** crossing near **Strobel.** Vicinity finds include agate, chalcedony, jasper, and quartz.

Site 2 **Antelope Draw/U.S. Highway 67** crossing near **Strobel.** Vicinity finds include agate, chalcedony, jasper, and quartz

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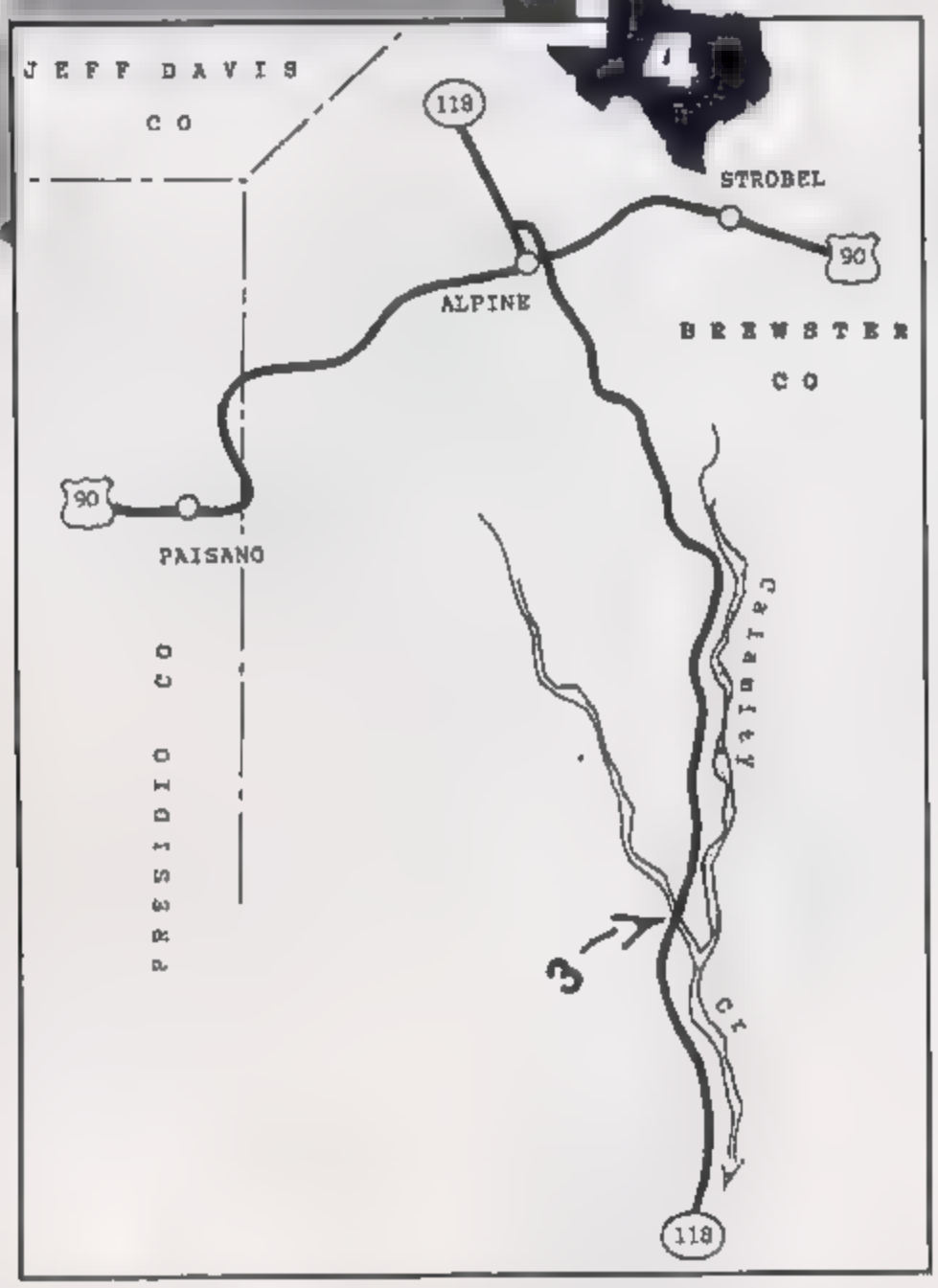
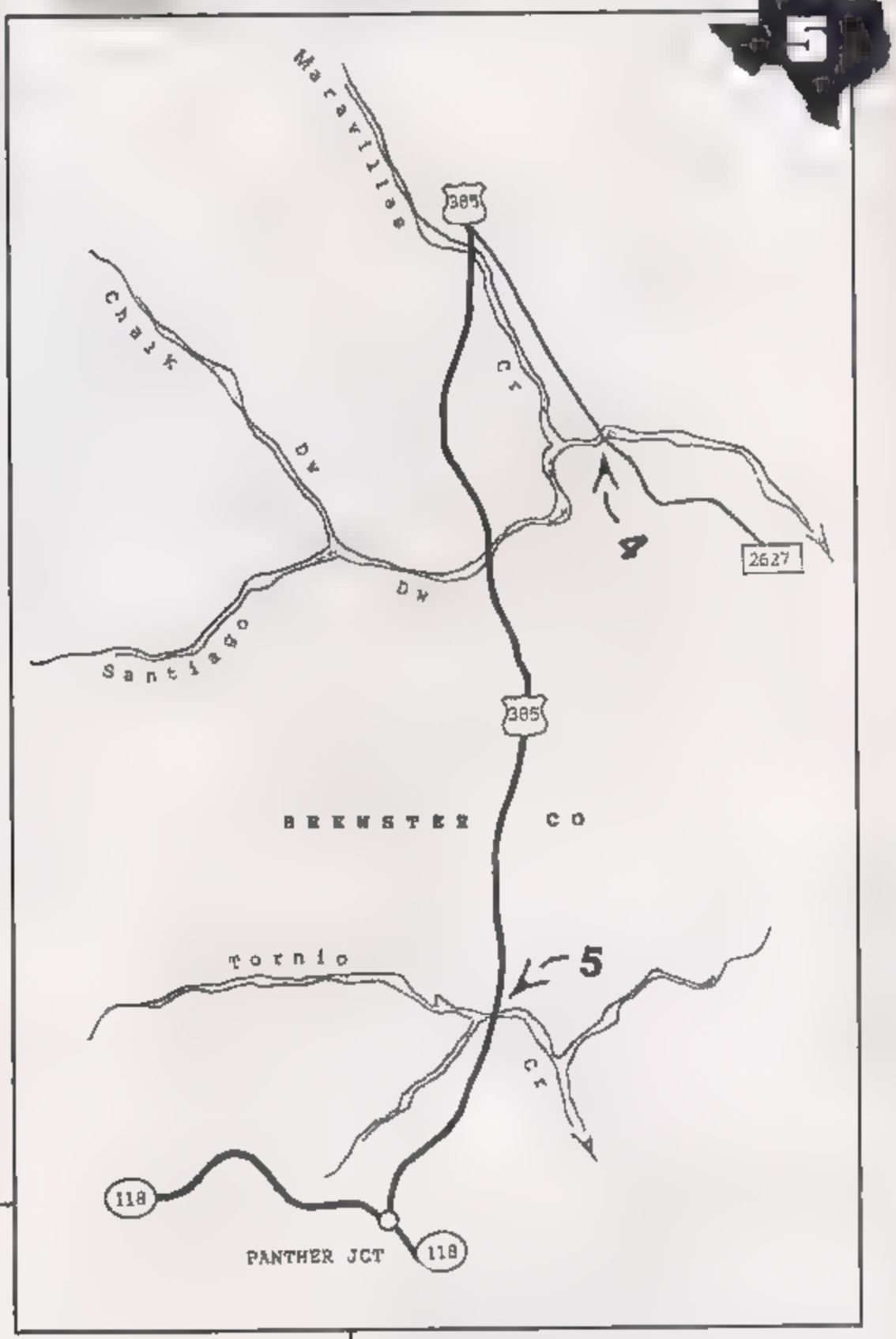
Roadside Panning Sites in Texas *from page 35*

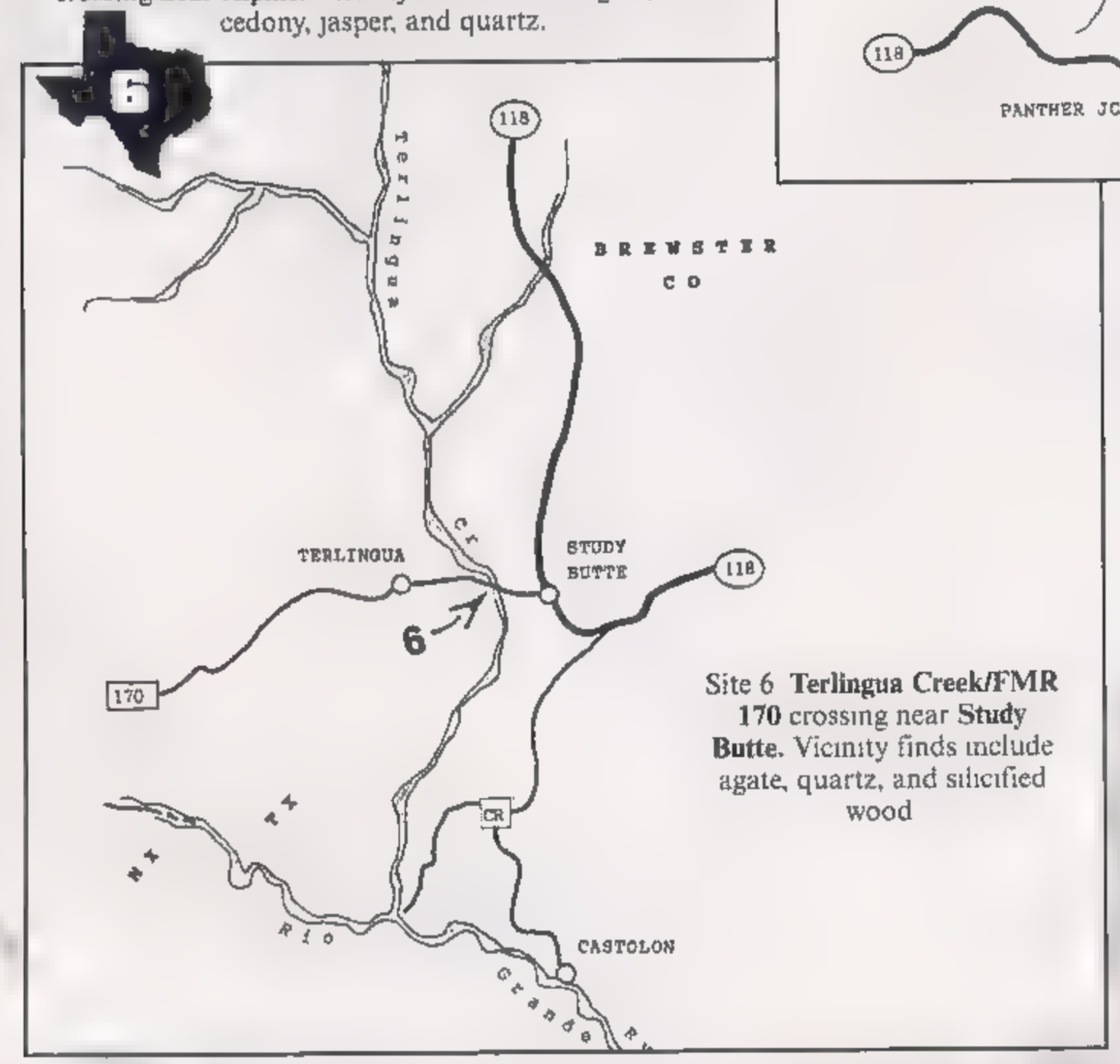


Site 3. **Tributary Calamity Creek/state Route 118** crossing near **Alpine.** Vicinity finds include agate, chalcedony, jasper, and quartz.



Site 4 **Maravillas Creek/FMR 2627** crossing near **Panther Junction.** Vicinity finds include agate, quartz, and silicified wood

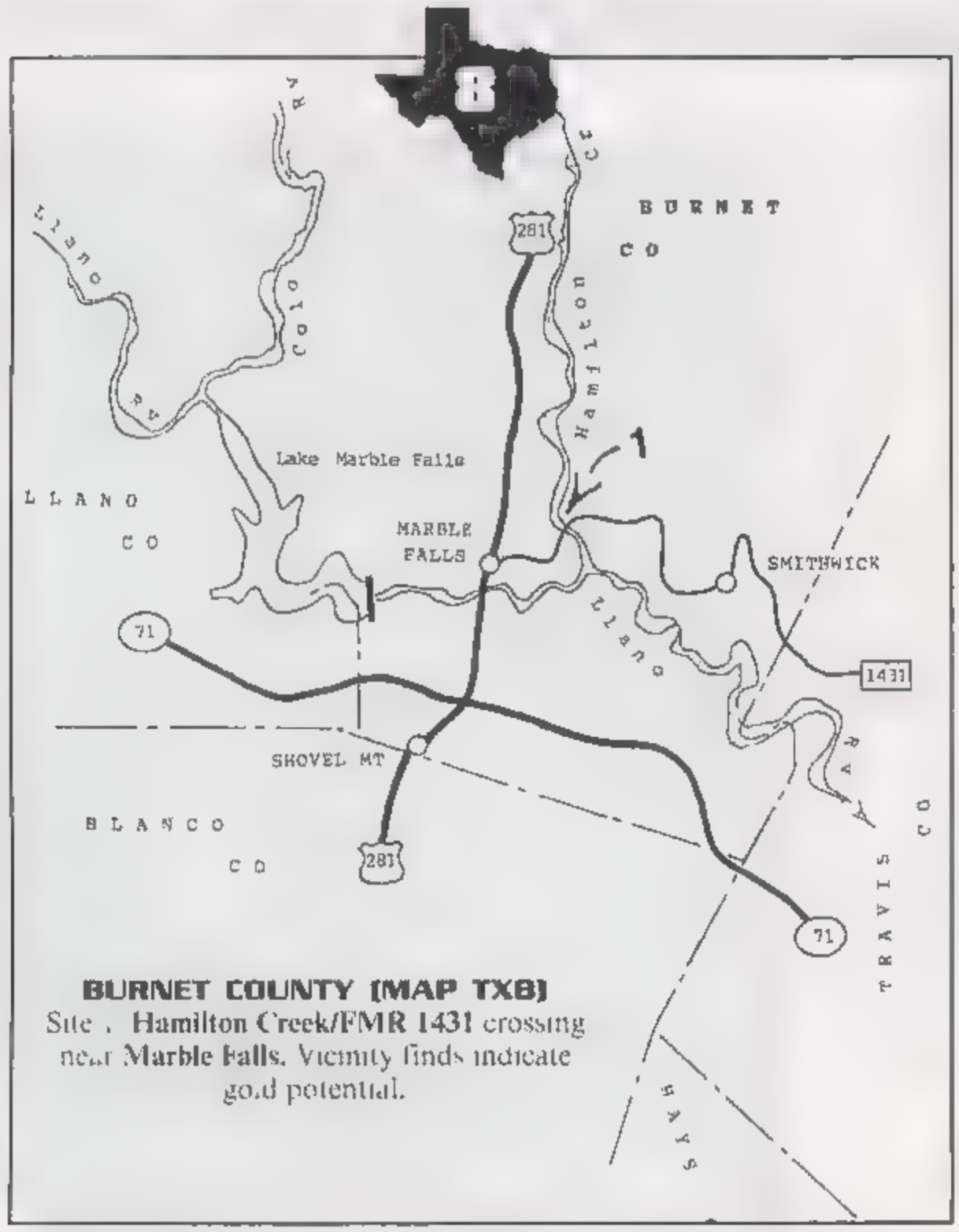
Site 5. **Tornio Creek/U.S. Highway 385** crossing near **Panther Junction.** Vicinity finds include agate, quartz, and silicified wood.



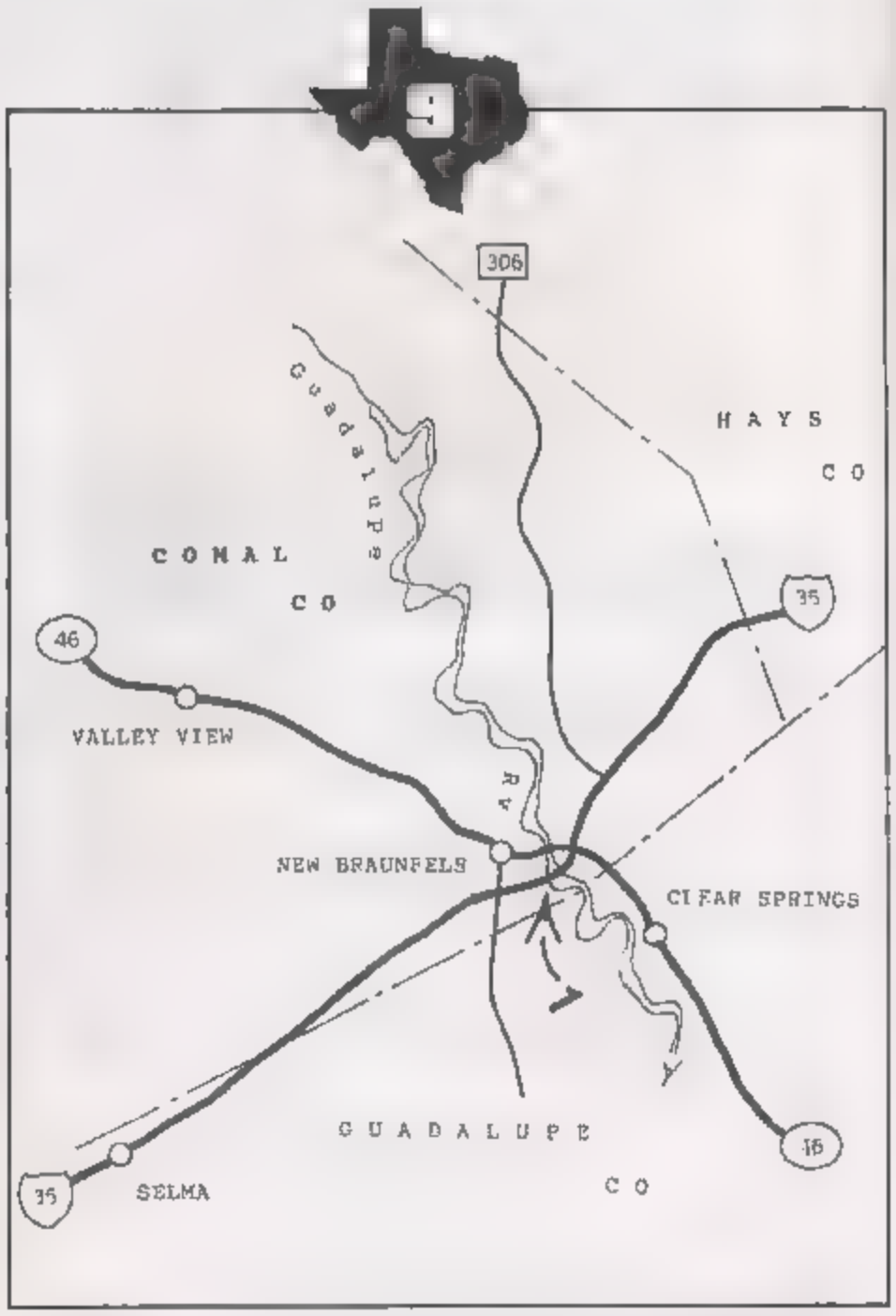
Site 6 **Terlingua Creek/FMR 170** crossing near **Study Butte.** Vicinity finds include agate, quartz, and silicified wood

continued on page 38

BURLESON COUNTY (MAP TX7)
Site 1 **Davidson Creek/FMR 60** crossing near **Lyons.** Vicinity finds indicate silicified wood potential
Site 2 **Yequa Creek/State Route 36** crossing near **Quarry.** Vicinity finds indicate silicified wood potential



BURNET COUNTY (MAP TX8)
Site 1 **Hamilton Creek/FMR 1431** crossing near **Marble Falls.** Vicinity finds indicate gold potential.



COMAL COUNTY (MAP TX9)
Site 1 **Guadalupe River/Interstate 35** crossing near **New Braunfels.** Vicinity finds indicate silicified wood potential

THE FRUGAL COLLECTOR

THE MOLYBDATES AND TUNGSTATES

Their Collectible Species Number Under 10

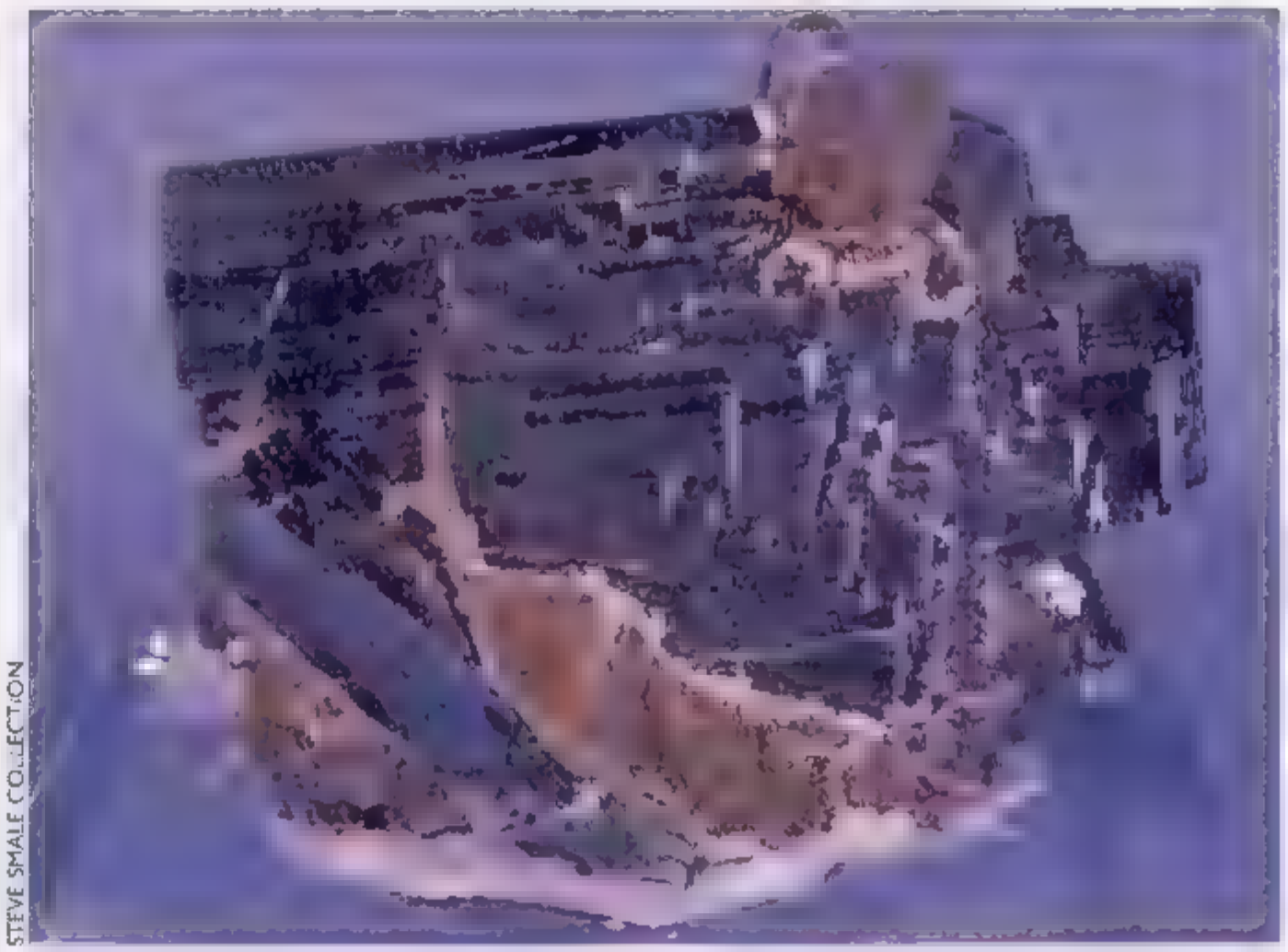
Story and Photos by Bob Jones

The number of species in the molybdate-tungstate chemical group that the average collector will see or own is under 10. This is because so many of these minerals are scarce and found only in very limited numbers. Of the molybdates, only powellite and angrenite are fairly common. The tungstates scheelite, huebnerite, wolframite, and ferberite are found in significant amounts and in pleasing, well-crystalized specimens and are available in quantity. Two rare tunsgates, stolzite and raspite, can sometimes be found, as well.

Chemically, all these species are closely related. Huebnerite is a manganese tungstate and ferberite is an iron tungstate. They form a series, in which manganese and iron can substitute for each other. Wolframite sits in the middle of this series, as it contains both iron and manganese. The latest textbooks, as well as the very useful 2004 edition of Michael Fleischer's *Glossary of Mineral Species* (Mineralogical Record), does not even list wolframite as a mineral. It was decided that, if iron dominates the mineral, it should be called ferberite, even though it may have a considerable minor amount of manganese in it. And as long as the iron content is less than the manganese content, the mineral is huebnerite.

Scheelite and powellite suffer the same chemical confusion. Scheelite is a calcium tungstate and powellite is a calcium molybdate. Since the two radicals WoO_4 and MoO_4 can interchange, there can be some confusion over their identity, which is probably best sorted out using a short-wave ultraviolet lamp as you will see.

Wulfenite, certainly one of the more colorful and collectible molybdates, is really the only significant lead member of the group. (Stolzite and raspite are also lead tungstates, but they are not found in quantity any more.) Lingrenite, a copper molybdate, and a few other uncommon species round out this group of collectible and colorful species. The last three tend to be uncommon and seldom occur in specimens significant enough to be entered in a competitive display. So aside from wulfenite, which is ubiquitous in the American Southwest, collectors are left with ferberite, wolframite (if you wish to use that term), huebnerite, scheelite, and powellite as the most collectible members of the tungstates and molybdates. Wulfenite is so appealing and abundantly available that it has been treated separately in this series (December 2003 *Rock & Gem*).



STEVE SMALE COLLECTION

This superb ferberite from near Pansquiera, Portugal, was first reported to be wolframite, a name no longer in use.

Scheelite is named for the Swedish chemist Carl Wilhelm Scheele (1742-86). Scheele was an extremely prolific chemist and a leader in the study of minerals during his lifetime. He investigated a variety of mineral substances and, perhaps more importantly, was an advisor to a number of contemporary scientists. Scheele lived in Sweden, where a couple of rather complex ore bodies were mined 300 years ago. He is credited with being the co-discoverer of that vital life gas, oxygen.

Scheele is credited with investigating scheelite, from which he extracted a substance he called tungstic acid. In Swedish, "tung" means "heavy" and "sten" means "stone." The tungstic acid turned out to be a tungsten oxide. Unable to extract the metal from this "acid," Scheele referred it to two famous Spanish chemists, Don Fausto and Don Juan Jose d'Elhuyer, graduates of the Institute at Freiberg.

The d'Elhuyer brothers investigated the "heavy stone" and tungstic acid. They also investigated a related mineral, which came to be called wolfram, an

iron, manganese tungstate. Through experimentation, they actually were able to break down the tungstic acid and obtain the first relatively pure bits of the metal tungsten.

Today, the importance of tungsten is well known. The steel industry uses huge amounts to harden steel. Many high-speed drill bits and cutting tools are made of tungsten steel, though titanium is favored by many now. The tungsten filaments in your electric light bulbs do very nicely in the absence of oxygen.

Automobile mechanics know the value of tungsten, not only in their cutting and drilling tools, but in the ignition systems of older cars. Inside the distributor, the contact points signal the ignition coil to send high voltage to the spark plugs. These make contact thousands of times a minute when the engine is run at high speed. Each time they are or close, an electrical current is sent to the ignition coil, which converts that current to a multithousand-volt charge to each spark plug, which in turn ignites the fuel/air mixture in each cylinder. Those contact points are made of tungsten metal.

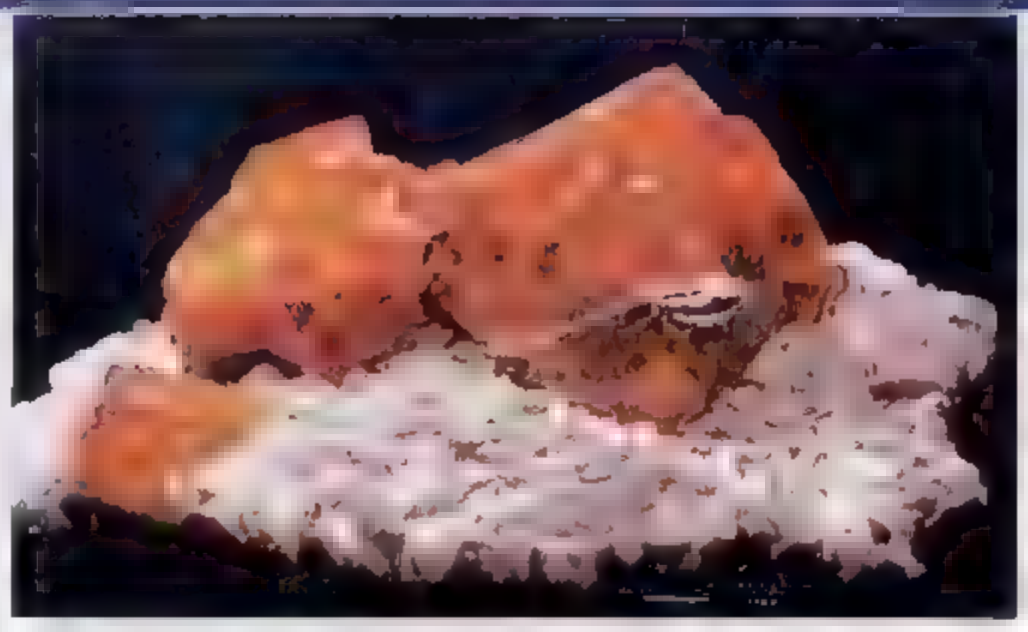
Scheelite is a relatively uncommon collector mineral, as there are a limited number of localities that produce fine crystals. On the other hand, there is a sufficient quantity of massive scheelite to satisfy industry's needs. Currently, both India's basalt quarries and China's mines are producing fine well-crystallized specimens of the scheelite-powellite series.

These two minerals form a series in which calcium combines with the tungstate radical (WO_4) to form scheelite, and the molybdate radical (MoO_4) combines with calcium to form calcium molybdate, or powellite. Since each can substitute for the other, it is very common to find molybdenum-rich scheelite and vice versa. The differences between the two are significant, especially under the ultraviolet lamp.

Interestingly, on the Periodic Table of Elements, the symbol for tungsten is W, for wolfram, the German word for tungsten. The mineral name wolframite may also have been dropped because it could be confused with the accepted element name wolfram, which is in common use in Europe and elsewhere.

Scheelite was found early on in the high-temperature hydrothermal veins in Austria and Bohemia. Schleggenwald and Zinnwald produced fine specimens associated with cassiterite, a tin oxide. In fact, scheelite was at first thought to be a tin or perhaps an iron mineral.

Crystals of scheelite form in lovely tetragonal-dipyramidal crystals that often take on the appearance of the octahedron and so are often referred to as pseudo-octahedral. This crystal form is the most common one seen in scheelite crystals from India, Italy, Bohemia, Korea, and elsewhere.



China is now one of the world's good sources of choice, gemmy scheelites in pseudo-octagonal crystals.

Among some of the earlier specimens found were lovely, small, sharp, gray crystals from the Piedmont area of Italy. These are no longer often seen, nor are the classic specimens from the German localities.

Two localities in Korea produced quantities of superb scheelites: the Tae Wha and neighboring Tong Wha mines and the Wolsak Mine. The Tong Wah crystals were numerous and are associated with, and sometimes attached to, lovely quartz crystals. The prettiest specimens are clear quartz crystals with a sharp pseudo-octahedral scheelite sticking to one of the quartz prism faces. Their color is dark, tending toward brownish-violet. These crystals, which could reach upwards of 4 inches on an edge, do not respond well to ultraviolet excitation. The Wolak crystals are a lighter color, even shading into tan or light brown, so they do respond nicely.

The deep gold mine at Morro Velho, Brazil, is a source of richly colored scheelite.

Sources in China include Sichan, Guizchou and Jiangxi provinces. Chinese scheelites are typically pseudo-octahedral. What makes them very appealing is that they are very colorful and gemmy, though I have not seen any gems cut from them yet. They are also a vibrant bright orange to yellow-orange, which makes them extremely attractive as collector specimens. The Sichan crystals occur on muscovite, a light-colored mica, and have a rich reddish-orange color. The association with the bladed mica, which in itself is attractive, makes these specimens very appealing to collectors. The scheelites may also be associated with minor calcite. The availability of Chinese scheelites will vary according to mining activity and the ability of dealers to go to that vast country and obtain specimens for sale.

The crystals from India are found in the trap quarries of the Nasik area. The term "trap" refers to large deposits of basalt that were originally mined in this country for rip-rap, crushed rock used in road construction. Rip-rap gradually became known as trap rock, and quarries of basalt became trap rock quarries.

About 30 years ago, the first powellite crystals began showing up in the Pandulena Hills near Nasik. Today, more and more powellites are being found and saved as specimens. They are typically pseudo-octahedral and a bright white to straw yellow, with the finest specimens edging toward a rich honey color. The larger crystals reach 2 inches on an edge and all show a fine luster. Often, the powellites occur singly on matrix, but some are seen as twinned crystals or in parallel growth. They occur on quartz, laumontite, stilbite, and fluorapophyllite, which helps make them even more appealing to collectors.

Similar powellites occur in the Jalgaon area, while small, slightly greenish crystals come from Malegaon. All show a fluorescent response to varying degrees, with the lighter-colored crystals responding best. Their color runs from a whitish yellow to rich yellow. However, while scheelite and most powellites respond to shortwave ultraviolet light, the powellites from India respond to long-wave excitation. The availability of these superb crystals varies and is never abundant, though the sources continue to operate and, hopefully, produce! The same is true of the scheelites from Chinese sources.

continued on page 43

The Frugal Collector *from page 41*

Scheelite is also found on the Chukota Peninsula at Tenkergin, Magadan oblast', Russia. Fine orange crystals to 2 inches have been found in fair quantity in recent years. These have appeared on the American market sparingly, as most are sold in Europe, where scheelite is highly regarded. Asturia, Spain, also produces fine orange crystals under 2 inches and in limited amounts.

Some of the nicest yellow to yellow-orange crystals from North America have come from the Santa Cruz area of Sonora, Mexico. The Mexican deposit is better known for very attractive schorl, the black variety of tourmaline which occurs in coal-like diverging clusters and heavily striated crystals with sparkling velvety prism faces and terminations that are very smooth with high luster. It has produced nodules of these black beauties a foot or more across. Enhancing some of the tourmaline groups are yellow white, yellow, and yellow-orange dipyramidal scheelite crystals 2 inches or longer. Some of the crystals are decidedly rounded, while others are razor sharp on the edges. Some show multiple growth patterns on the faces, while others are glass smooth and lustrous. Many have gemmy sections in them. A few of the crystals tend to be greenish, but the pale honey-colored crystals, which can be gemmy, are more common. It is my understanding that the first of these crystals was found as float in a dry riverbed.

These Mexican crystals vary in composition between scheelite and powellite. Remember, scheelite is a calcium tungstate and powellite is a calcium molybdate. The chemistry of these crystals is revealed under shortwave ultraviolet excitation. When the crystal in question tends toward a yellow UV response it contains more molybdate than tungstate. These radicals can substitute for each other promiscuously. If the quantity of molybdate exceeds that of tungstate, the specimen is considered to be on the powellite side of the equation. If the UV response tends toward the white to bluish color, the metal content in the crystal is higher in tungstate than molybdate, and the mineral is a scheelite. The neat thing is that some Mexican crystals will show sections that give a yellow or a blue response as you rotate it under the lamp. This shows a near 50/50 mix of the two metal radicals. I had one Mexican crystal analyzed, and it was shown to contain 49 percent molybdate and 51 percent tungstate, making it a scheelite, but only just!

This same variation of blue-white versus yellow response under shortwave UV

The wolframite/ferberite coming from Chenzou, Hunan Province, China is usually labeled as wolframite.

light was used by prospectors and people in the industry once portable ultraviolet lamps became available in the late 1930s. Until that time, ultraviolet energy was produced by sources like the iron spark, that also gave off unfiltered white light which interfered with seeing the true response of the mineral. Once a filter was made that could effectively block most white light produced by a shortwave ultraviolet lamp, mineral responses were more easily seen and the perceived color more accurately described.

In addition to making it easier to identify scheelite and powellite in the field, the ultraviolet lamp can also help to tell the ratio of scheelite/powellite, which relates to the value of the ore and ease of smelting, since the molybdate content tends to increase the cost of smelting. If the ore is more costly to smelt, the miner receives a lower return. The amount of molybdenum in a given specimen, then, was an important factor in metal recovery costs.

As World War II approached, it became obvious that the need for tungsten was going to increase exponentially. The supply of scheelite and powellite, the main sources of this strategic metal, was limited. But prospectors soon realized scheelite was a common gangue mineral in many gold mines in the West. Dumps that seemed to contain nothing of value would light up at night under the portable shortwave lamp. They contained huge quantities of mined and discarded scheelite!

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The Frugal Collector *from page 43*

Perhaps the best example of this happened near Victorville, California, where some gold mines were operating. Large masses of what looked like quartz were nearly scheelite. These were profusely scattered all over the desert slopes. The amount of scheelite was so great and so easily collected by ultraviolet lamp that the locals, including kids, energetically collected these float rocks and sold them to the nearby mill as tungsten ore. These rounded boulders and rocks were so profuse and scattered over such a wide area that locals called the region "the potato patch."

With the recent increase of interest in fluorescent minerals, massive scheelite has now become a viable item on the specimen market. Under the shortwave lamp, scheelite glows a brilliant blue-white to white. It matters not that it is only crystalline, has no crystals, and is locked in granite or similar rock. As long as the patches of scheelite are large enough and respond brightly enough, a good scheelite rock will stir the heart of any collector of fluorescent minerals.

When I was working on my master's degree in Connecticut, one of my favorite collecting sites was the old tungsten mine in Trumbull. Fifty years ago, we could wander in and dig to our heart's content. The dumps were not huge, but they yielded rocks with bright patches of scheelite in them. The dumps also held massive colorless topaz, which many mistook for quartz. For the fluorescent collector, there were also chunks of crystalline fluorite that had the unusual property of thermoluminescence; they glowed a ghostly green when heated in an oven. Another really rare find here was pseudomorphs after scheelite, sharp, coal-black, pseudo-octahedral crystals of wolframite just under an inch, completely replacing the scheelite. In all my visits here, I only found one such crystal. Now the place is a city park and collecting is controlled.

Wolframite is the name still given to an iron, manganese tungstate. It sits more or less in the middle of a series formed by manganese tungstate (huebnerite) and iron tungstate (ferberite). Which mineral name is used depends on the chemical content of the mineral, and that is not easily determined.

A good example of this problem occurred with specimens from Europe's most important source of wolframite: ferberite Panasqueira, Portugal. Wolframite, in spite of the latest information, is still considered part of the series formed by huebnerite and ferberite, an iron tungstate. As you visit dealers, you might see a specimen from this Portugese locality labeled "wolframite." That's what the material was thought to be when it began coming into the specimen market about 40 years ago. Later studies showed the beautiful black blades of tungsten ore were actually ferberite. You'll run across this confusion in the older mineral reports as a large quantity of this material was brought from this mining region, which is still operating because of the state of fine minerals it produces. Associated with the ferberite are clear quartz, sharp metallic arsenopyrite crystal clusters and beautiful white to violet-zoned prisms or hexagonal discs of fluorapatite. Photographs of Portugese specimens are frequently seen in books, as this deposit was a major, prolific producer of fine specimens.

This Portugese ferberite from the Barroca Grande Mine, near Fundao, is seen in black striated blades up to 6 inches long and up to 3 inches wide. The terminations are square and sharp. The Barroca Grande fluorapatite can be disc-shaped, some of the best ever found anywhere. The ferberite usually tabular is found here and elsewhere as tapered spear-shaped crystals to an inch or two long in subparallel clusters. When tested, the iron content of the so-called wolframite crystals from Panasqueira proved minimal enough to have the specimens declared ferberite.

At the opposite end of this series, we find very attractive huebnerite, a manganese tungstate. Manganese is another element whose discovery involved Carl Scheele. Scheele urged Peter Jacob Hjelm to continue investigating this element, and in 1778 the metal was discovered.

Currently some of the mines of Peru have produced marvelous huebnerites from several ore bodies, including Julcani, the San Cristobal Mine, the Huanzala Mine, and Pasto Bueno. The ore bodies here are vein-type tungsten deposits, which produce a number of species: rhodochrosite, native silver wires, arsenopyrite, lovely quartz, and several other collector species.

The Peruvian huebnerite ranges from almost acicular narrow, elongate blades to 5-inch blocky, black crystals, often with quartz crystals. On thin edge, many of these crystals flash a red identifying color and some are even a lovely dark mahogany. At the San Cristobal Mine, some of the huebnerites are pseudohexagonal, an unusual form for this mineral species.

Another early source for fine wolframite, or ferberite, if you prefer, was one of Bolivia's most famous mines, the Unificada de Potosi in Potosi. In 1944, it seems a goatherder was chasing some of his flock up the slope of a fairly steep hill. Goats can climb better than humans, so to get to the animals, he had to climb hand over hand, grasping clumps of grass and

continued on page 46

small bushes. One bush suddenly tore out by the roots, and tangled in the roots of that bush were clumps of silver wires! The result was the discovery of South America's richest silver deposit.

While Potosi wolframite is not so well known, one other species has certainly won a place in the hearts of mineral collectors: phosphophyllite. The Potosi Mine has yielded the world's finest example of this rare zinc, iron, manganese phosphate first found in Germany, a 7-inch-long twinned crystal of superb sky blue color on matrix. This specimen now resides in the Houston Museum of Science.

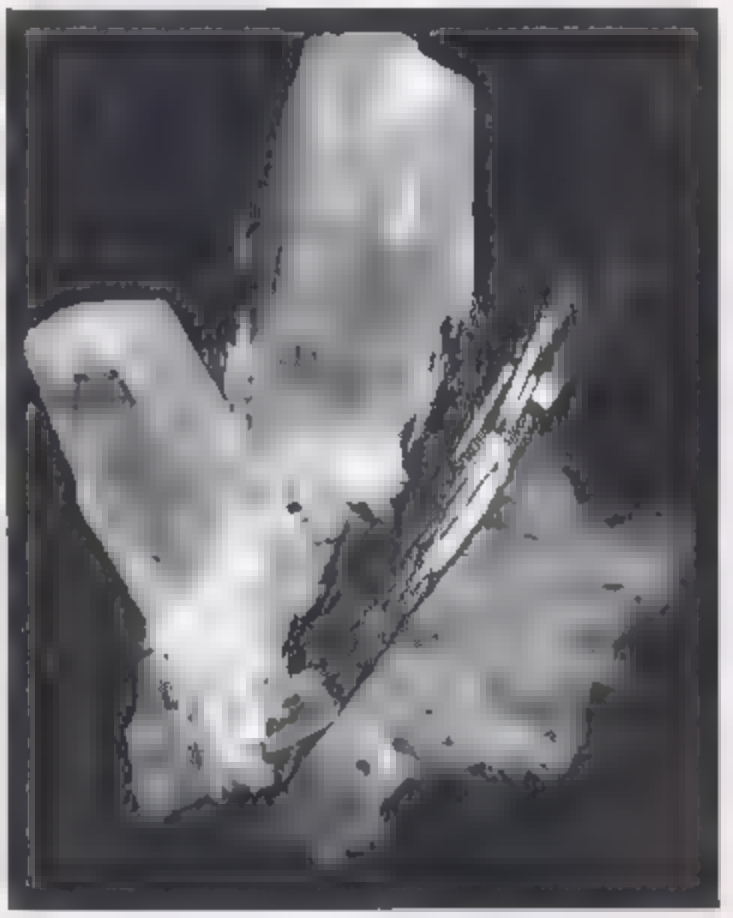
Here in the United States, the huebnerites have been found in several mines in the San Juan Mountains, in the southwestern portion of Colorado. The huebnerites from the Adams and Red Bonita mines, just north of Silverton, are found as brownish to mahogany-red thin blades in diverging sprays. The crystals are striated and relatively short, seldom reaching more than an inch long, but in exceptional cases up to 6 inches long.

An interesting anecdote about the Adams Mine involves Ed McDole, a mineral collector about whom there have been more tales told, true or not, than about any other collector/dealer in the 20th century. Ed ranks among the classic characters of our hobby.

Ed was an itinerate contract miner who worked in Butte, then struck out on his own, going into closed mines to dig specimens. He was very successful in this endeavor and became very well known as a source of choice specimens.

One of his collecting techniques was to go into a mining town and hang around the local bars during shift change, talking to the miners about minerals and what they might have that he could buy. He would also ferret out collecting information he could later use. One of his favorite hangouts was Silverton, Colorado, where specimens of gold, quartz, fluorite, and rhodochrosite were to be had in quantity. Ed, who had diabetes, stayed at the Adams Hotel while in Silverton. In fact, he died in that hotel and is buried just north of town. What I find interesting is that, when he died, a stack of beer flats full of fine huebnerites he had just collected from the Adams Mine just north of Silverton was piled next to his bed. I do not know what happened to the huebnerites, nor to his well-known collection of superb minerals. The collection was always in his car, but was not there after he died, and it seems never to have surfaced since. You might be interested in reading about Ed and his "lost" collection in my book *A 50 Year History of the Tucson Show*.

Another tungstate that you might watch for, though it is considered a rare mineral, is stolzite. The problem here is the mineral may well occur more often than thought, but it is not easy to recognize. When it does occur, the crystals are rather small, usually measurable in millimeters. Stolzite is a lead tungstate and forms a series with raspite, a really rare lead tungstate. The two minerals are dimorphs; they have the same chemistry, but different crystal forms. Stolzite is tetragonal, while raspite is monoclinic.



Peru has been producing choice mahogany-colored huebnerite in the last decades. This 4-inch crystal rests on fine calcites.

Stozite was first identified from the old tin mines of Zinnwald, Bohemia. It was never a significant collector species until more recently, when it was found at the Proprietary Mine in Broken Hill, New South Wales, Australia. This remarkable silver, lead, zinc deposit produced a wonderful suite of fine collector minerals, including brilliant galena, choice gemmy rhodonite, fine silver species, some of them quite rare, wulfenite, and choice cerussite. This remarkable deposit was found by Charles Rasp, for whom raspite was named. Broken Hill is Australia's best-known specimen mine, but has been mined out. Fortunately, fine Broken Hill specimens are still extant.

Small amounts of this mineral have been found in several places in the Huachuca Mountains southeast of Tucson, Arizona. In particular, the Cohen Mine in the Dos Cabezos Mountains was a minor producer of raspite, but the Cohen Mine is far better known for its bright-orange scheelites, pyramidal crystals up to 4 or 5 inches high. They are always associated with quartz. The finest Chone Mine scheelite ranks among America's best, and the best-known single specimen is housed in the Arizona Mineral and Mining Museum Foundation's collection in the Arizona State Museum, Phoenix.

For Eastern collectors, the Manhan Lead Mine, a small lead deposit in Southampton, Massachusetts, has yielded some tiny crystals. This old deposit has long been a favorite haunt of collectors seeking wulfenite. Since wulfenite and stolzite can resemble each other, I suspect more than a few of these "wulfenite" specimens are actually misidentified stolzite. The tiny crystals occurred in small vugs in gray quartz and were easily missed.

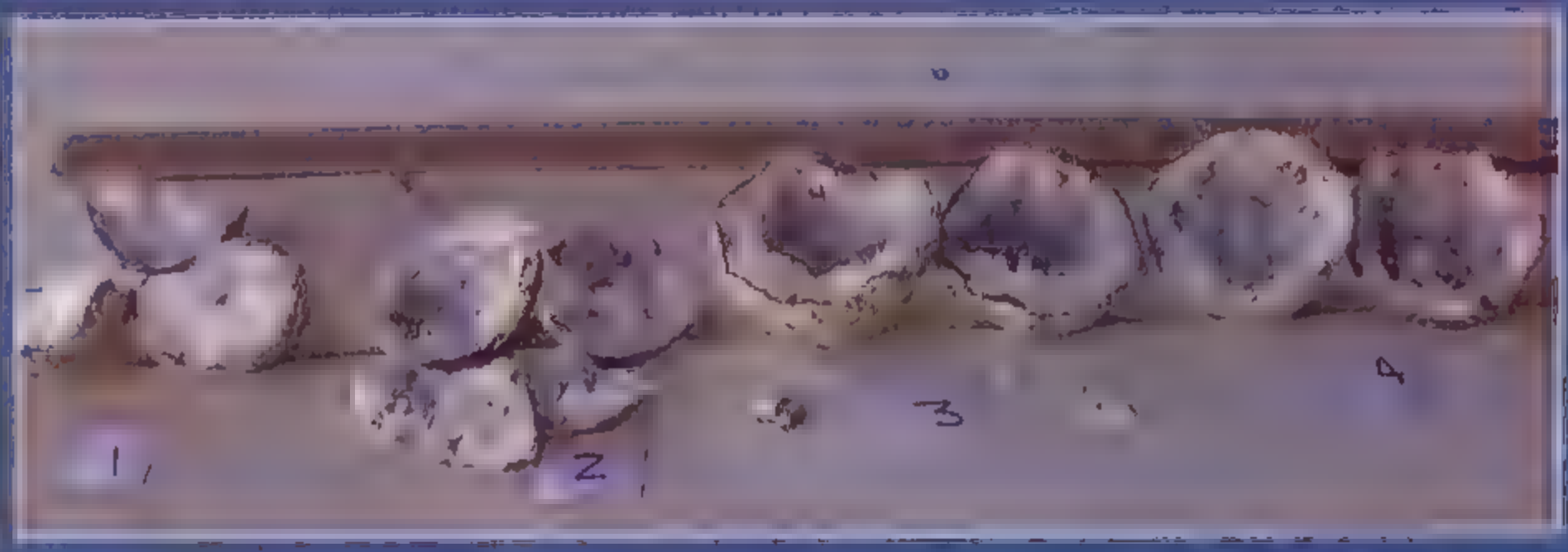
Since its initial discovery in Europe, stolzite remained relatively insignificant until some stunning crystals were found at Tsumeb, Namibia, a most remarkable complex copper, zinc, lead mine. The initial discovery was made in 1982, and a series of superb pyramidal stolzite crystals to an inch in size were found. Twelve years later, another pocket was opened that produced fine stolzite exceeding an inch in length. The Tsumeb finds have not been huge, but sometimes little-known and difficult-to-recognize minerals are mistakenly identified and hit the market just waiting for some knowledgeable collector to come along and make a lucky buy. Some specimens become separated from their labels or fall into the hands of someone who is not well schooled in minerals, and the occasional specimen gets misidentified or misplaced and can be found for trade or sale.

The most popular and colorful species of this group is wulfenite. It's one of my favorite collector minerals, perhaps because I've had some success in finding it in Arizona and Mexico mines. I described wulfenite in great detail in the December 2003 issue of *Rock & Gem*.

In spite of a somewhat limited variety of species, the tungstate-molybdate mineral group is a wonderful group to collect. While wulfenite is readily available, the average collector can still obtain excellent examples of other species in this chemical group. Fine crystals, many very colorful and in attractive groupings, offer enough variety to make them well worth collecting. There are superb orange scheelites and fine yellow powellites, lustrous black ferberite/wolframite, mahogany-colored huebnerite, and wulfenite in its riotous yellows and reds. Each of these species surely adds interest and appeal to any collection. ■

ROCK & GEM

HOW TO PICK A HOLLOW GEODE



Paleontologists for a Day

Go Bone Digging with Dinosaur Journey Expedition

Story by Lori Lamb

DARYL LAMB PHOTO

Museum volunteers supervise as expedition guests delicately remove matrix from the bones with screwdrivers and dental picks.

As most any serious mineral collector can attest, Colorado is a state rich in mining and associated mineralogical history. The stunning rhodochrosites from the Sweet Home Mine, crisp blue barites from Stoneham, and pyrites from the Eagle Mine at Gilman are standards in many premier mineral collections. Names like Cripple Creek, Creede, Telluride, and Leadville project mental images of stereotypical Old West mining towns. And yet, Colorado has another very distinguished, somewhat parallel history that may not come as quickly to mind, one whose roots lie not in the metamorphic and igneous underpinnings of the Rockies, but in some famous sedimentary formations on the Colorado Plateau. A paleontological history that dates back to 1877, when discoveries by the famous dueling paleontologists Othniel Marsh and Edward Cope opened the book on fossil collecting in Colorado, is still unfolding today.

To the west of the Rockies, the Colorado Plateau covers large parts of four contiguous states: Colorado, Utah, Arizona, and New Mexico. Its rich geological history is punctuated by such features as the Grand Canyon, Monument Valley, Zion National Park, Glen Canyon, the Arches National Monument, and even the San Juan Mountains. At various locations within the boundaries of the plateau, exposures of Mesozoic formations of the Triassic, Jurassic and Cretaceous period beckon for arguably the most exciting, if not the highest-profile, fossil hunting: dinosaur hunting. The plateau's arid climate and lack of thick vegetation allows for greater exposure of and access to the fossil record contained within its stratigraphy. And the significant frequency of accessible outcrops of the famous Morrison Formation makes the area attractive to both professional and amateur paleontologists seeking that find of a lifetime.

On a smaller scale, a line drawn from Dinosaur, Colorado, south to Grand Junction, over to Green River, Utah, through Price, and back north to Vernal roughly outlines an area that has been dubbed the "Dinosaur Diamond." This area is particularly rich in dinosaur related locations, monuments and museums, and is even connected by roads designated the Utah/Colorado Prehistoric Byway. It is in this vicinity that the Museum of Western Colorado offers an opportunity for members of the general public to participate in an actual dinosaur excavation project. The Dinosaur Journey Expedition program, based in Fruita, Colorado, and sponsored by the Museum of Western Colorado's paleontological division, allows participants to "dig for dinosaurs in the colorful 150 million-year-old badlands of the Morrison Formation" (program brochure). Since our family vacation destination was Colorado, this opportunity was too good to pass up. After obtaining additional information online and paying the advance fees, we were set for a July 21, 2005 dig.

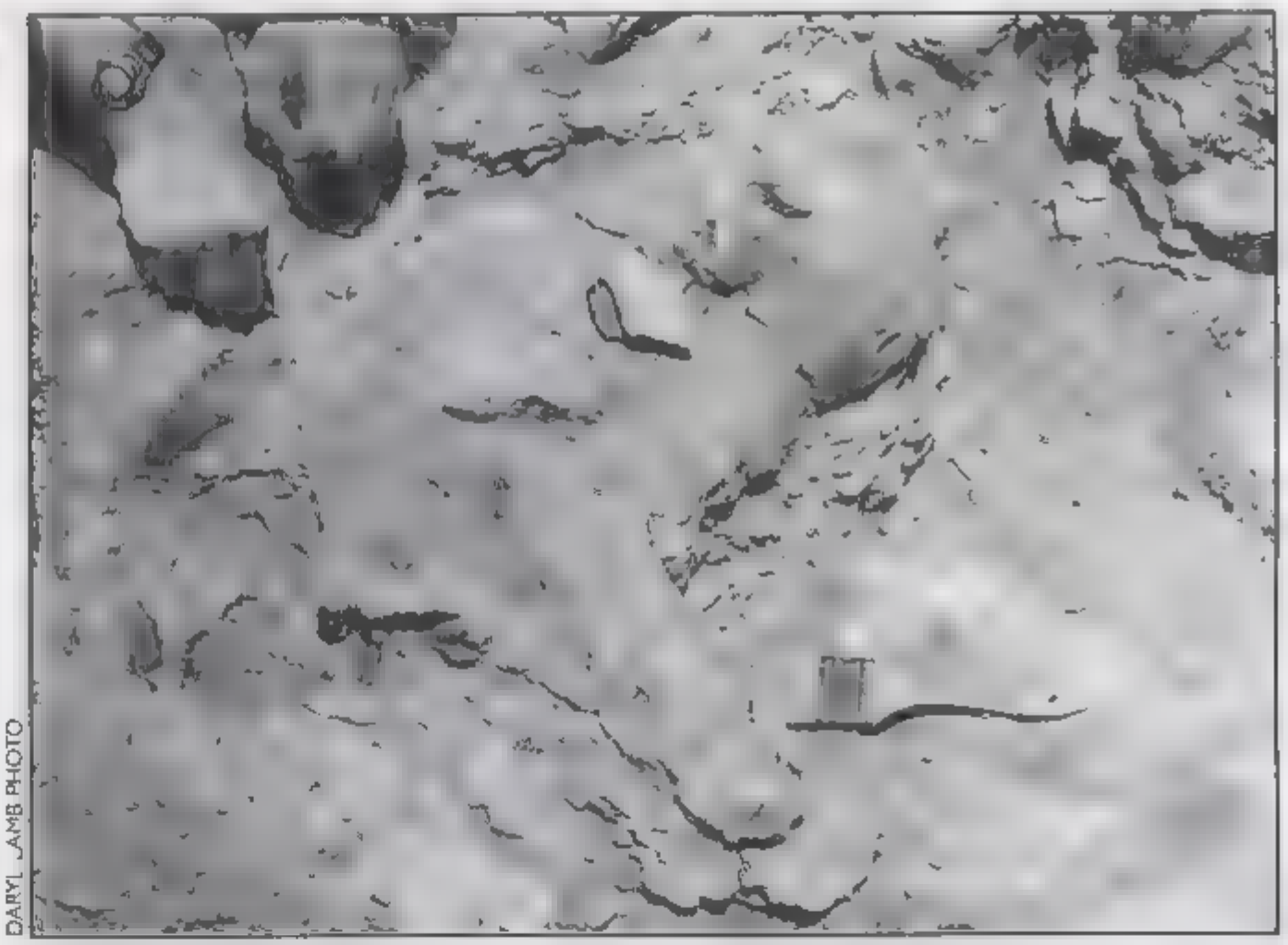
Fruita is in Mesa County along Interstate 70, west of Grand Junction and about 19 miles from the Utah state

The Colecting dinosaur fossils in this area dates back at least to the mid 1880s, when local residents collected and sold them as curios. Their secret got out when, in 1900 and 1901, Elmer Riggs, then Assistant Paleontologist at the Field Museum of Natural History in Chicago, excavated large sauropod bones at two sites south of the Colorado River near Fruita. These sites have been immortalized as Dinosaur Hill and Riggs Hill and can be visited today. Mesa County has been the site of numerous significant dinosaur fossil finds over the last hundred years, so it does seem fitting that the Museum of Western Colorado chose Fruita as the site for its branch paleontology-focused museum. It is here that our exciting and very educational adventure began.

On the day of the dig, the temperature was forecast to be 105 degrees with only about 10 percent humidity. Though admittedly hot, it would not feel as oppressive as the 90-degree, 90 percent humidity weather back home in North Carolina. After breakfast, we gathered the assigned essentials of sunscreen, camera and hat, and assembled in the front lobby of the Dinosaur Journey Museum. Dig attendance is limited to around a dozen guests, as the quarry site is not very large. We were not the only ones who had traveled far for the experience. There were also participants from Maryland, England and Russia.

Our field coordinator, museum volunteer Don Chaffin, gave us a brief history of the expeditions and an outline of the day's agenda. Water breaks every 30 minutes, he stressed, would be absolutely enforced to prevent heat stroke in the deceptive combination of low humidity and high temperatures. By 9 a.m., we climbed in the vans for the 17-mile ride to the site, 150 million years back in time.

Just to the west of Fruita, the Morrison Formation rises up from the plateau in its signature exposures of maroon, gray, and gray-green banded patterns. It contrasts distinctly with all other outcrops and is often exposed in layers 50 to 60 feet thick, which contributes to the number of specimens found within the strata. The Morrison is the primary member of the Colorado Plateau formations that contains significant numbers of dinosaur bones, and is a mecca to those who seek its hidden treasures. The Morrison Formation was laid down late in the Jurassic period and represents its closing chapters, spanning from 155 million to 144 million years ago. It is composed of mudstones and sandstones from fluvial deposits of lake and floodplain silts. The formation actually contains five substrata that contribute to the fossil record in various ways.



DARYL LAMB PHOTO

A large Apatosaurus rib is surrounded by other bone fragments that will require careful extraction

The Tidwell member is the oldest stratum, composed of light-colored sandstone that extends over most of the Colorado Plateau. Next is the Salt Wash Sandstone member, another fairly prominent member. The Recapture Shale and the Westwater Canyon Sandstone members are apparently restricted to areas in New Mexico and Arizona. The youngest member, the Brushy Basin Shale, is a mudstone unit that is perhaps the most ubiquitous over the plateau. As we were to learn, this stratum has been a key factor in the paleontological success of the western Colorado digs, offering large concentrations of bones. Once one learns to recognize the Morrison, it serves as an easy marker. Indeed, numerous outcrops were evident on both sides of I-70 and off into the distance.

As we peeled off the interstate, the sign denoted Rabbit Valley. The van bounced along briefly down a side road, and suddenly we had arrived. The location was less than a mile from the highway. The actual dig site, known as the Mygatt Moore Quarry, was smaller than I had envisioned and covered with three awnings. The quarry dimensions were about 25 to 30 feet in length, 15 feet wide, and 6 to 8 feet deep into the Brushy Basin strata. The general area was indeed akin to badlands, with little vegetation. A small trailer served as a storage unit for supplies and tools. There were a couple of picnic tables, and off in the distance, the standard port-a-potty. The original quarry, no longer being worked, was excavated out in 2003, and the new, adjacent quarry was initiated in 2004.

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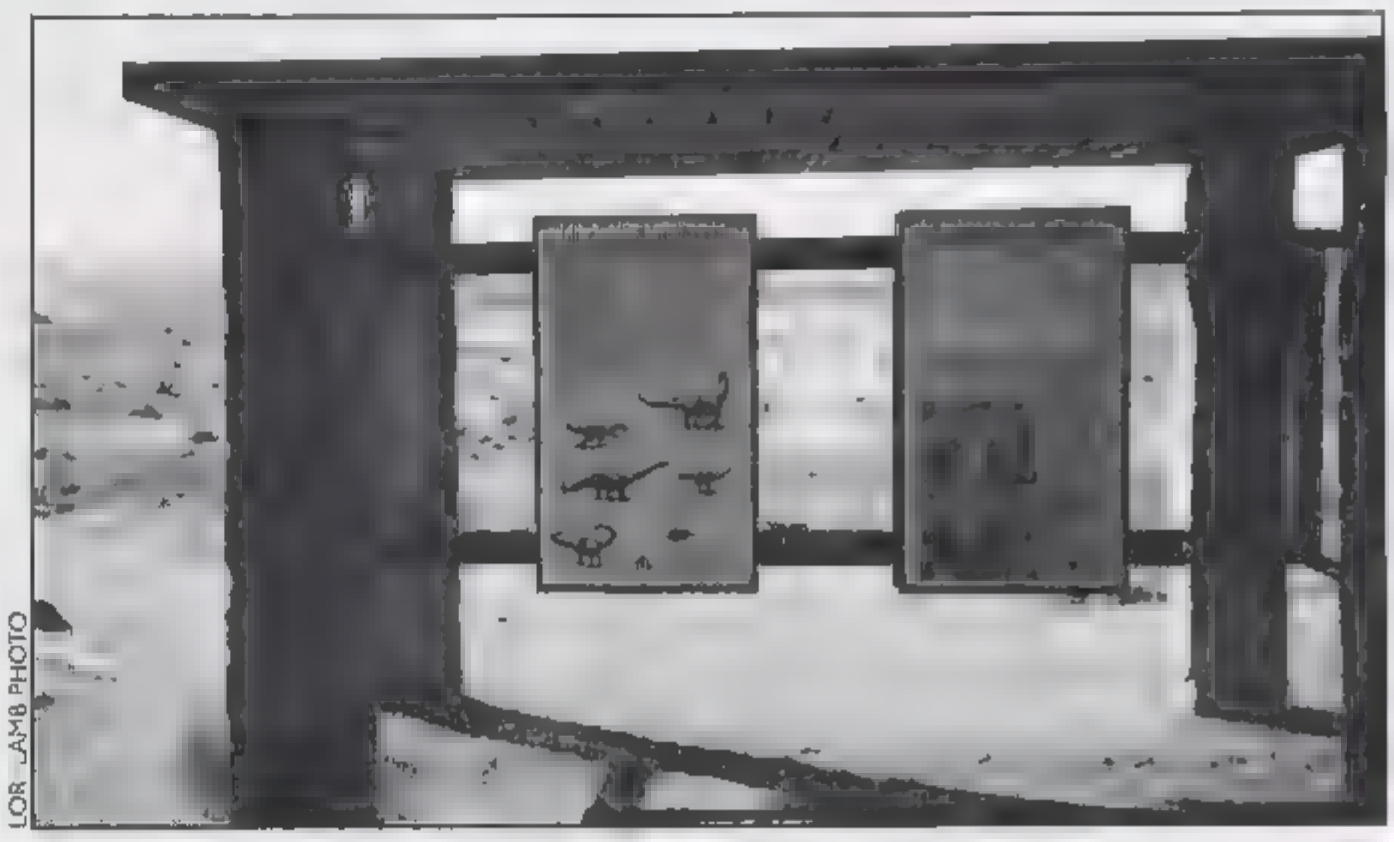

LORI LAMB PHOTO

The Mygatt-Moore Quarry, discovered in 1981, has produced dinosaur bones from several late Jurassic species.

Paleontologists for a Day *from page 65*

Our field coordinator, Don, assembled us for a brief history lesson about the Mygatt-Moore Quarry and its cast of characters. While out for a little rock-hounding in 1981, J.D. and Vaneta Moore and Pete and Marilyn Mygatt discovered part of the tail vertebra of an Apatosaurus exposed in the Morrison at this location. As responsible amateur paleontologists, they reported their find to the Museum of Western Colorado in nearby Grand Junction. In 1982, the museum obtained a permit from the Bureau of Land Management (BLM), which manages the public land that hosts the site, to begin excavations. As the excavation ensued, the findings began to give up clues about the features of this particular area some 150 million years earlier.

The excavation targeted primarily the Brushy Basin substrata, composed of mudstone from alluvial silt and pebbles. It seems the area was likely an ancient watering hole, probably a permanent one versus a seasonal one, that attracted the dinosaurs that wandered the otherwise arid savannah. The watering hole was surrounded by ferns, trees, and other vegetation that fed the large sauropods of the late Jurassic, and thus attracted the meat eaters that, in turn, preyed upon them. The distribution of bones found in the quarry shows no real association where they lay. There is rarely any bone articulation, as the bones and bone fragments are scattered and intermingled across species. Some even display tooth marks from the carnivores that scavenged them. Trampled, crushed, and even waterlogged, the bones tell of much activity at the watering hole.

The late Jurassic is known for its large sauropods, and they are much in evidence here. The quarry has produced plentiful specimens of both Apatosaurus, a vegetarian weighing 30 tons and measuring 65 feet long, and Camarasaurus, a bit smaller at 20 tons and 60 feet long. The fearsome meat eater of that period, Allosaurus, has also been found at the site. At roughly 1 ton and 27 feet long, he predates his Cretaceous brother T. Rex. The teeth of another meat eater known as Ceratosaurus have also been found in small quantity at the site.

These types of recoveries are the expected finds from late Jurassic Morrison formations. But the Mygatt-Moore has some hallmarks that set it apart from other similar sites. First, though small in actual area, it has been a prolific site, producing in its 23-year history more than 4,000 complete bones and roughly 9,000 cataloged pieces from eight different species. Among these specimens have been the highly coveted juvenile skeletons used by paleontologists to study the physical development of dinosaur species.

LORI LAMB PHOTO

Once the bone has been exposed, it is covered with plaster to stabilize it for removal and transportation.

Second, in addition to the copious number of large dinosaur bones, the site has revealed small fish bones, crayfish, turtles, snails, and plant material, all within the Jurassic strata and considered uncommon finds. This evidence further supports the working assumption that the site was once a permanent watering hole.

But its signature distinction came in 1990, when Janet Richke found the bones of what appeared to be an ankylosaur, a small quadrapedal vegetarian that utilized armor spiked plates for protection. Previously thought to be a creature only of the later Cretaceous period, her find became verified as the first Jurassic-period ankylosaur discovered in North America. And even though the turbulence of prehistoric activity had scattered the disarticulated bones over a 20-meter area, once removed, they provided a fairly complete skeleton that measured 10 feet long and 3 feet tall. To immortalize its resting place, the confirmed new species of ankylosaur has been named Mymoorapelta. All these events worked together to distinguish the 280-acre Mygatt-Moore site and the surrounding region of Rabbit Valley as a serious destination for the dinosaur hunter.

By now, everyone in our party was having visions of discovering a "Smithosaurus" or a "Jonesasaurus" to secure their place in paleontological history. So after assembling at our own watering hole, the Gatorade cooler, we approached the small quarry. Volunteers from the museum had preceded us to the site to prepare for the day's dig, and the site paleontologist Lorin King, was already hard at work. A professional paleontologist for 13 years and an admitted amateur hunter all his life, Lorin's responsibilities include oversight of the museum-sponsored quarries in Rabbit Valley. The presence of and subsequent oversight by such a professional are requirements of the BLM in order to permit a site. For us, the benefits were in his experience, expertise, and willingness to teach throughout the various phases of excavation and specimen identification.

Lorin reviewed the rules of the site: dig slowly and at a low angle; leave anything found in place for identification and mapping; don't break a bone; and, again, take water breaks every 30 minutes. To ensure that everyone had a memorable and educational experience, Lorin assigned each family group to one of four different sections being currently worked at the dig. Each group worked with a seasoned museum volunteer to teach us techniques and I'm sure to some degree, to protect the bones from us novices. Each of us collected a bucket, whiskbroom, dustpan, hammer, flat head screwdriver, garden trowel, fine-haired 2-inch paintbrush, dental picks, and a foam pad to protect our knees.

My husband and son and I had been assigned to work an area adjacent to an already partially excavated Apatosaurus rib. The bone, with a smooth blackish patina and fine, offset striations, protruded from the surrounding grayish mudstone. Our first assignment was to remove the adjacent overburden in anticipation of trenching around the rib. Lorin masterfully demonstrated the technique of carefully and slowly "plowing" the brittle mudstone with the screwdriver, introduced at about a 20- to 30-degree angle. If resistance was met, a slight tapping with the hammer usually loosened the stubborn area.

With some trepidation, we began. We loosened mudstone and alluvial pebbles with the screwdrivers, trying to proceed with care. At frequent intervals, we used the whiskbroom and dustpan to sweep the site clean to expose the next working area. Becoming absorbed in the task at hand, it became easy to forget to progress slowly, but the volunteers gently reminded us to scale back the pace and to carefully scan the debris for any bone fragments.

Sure enough, as we entered the level flush with the protruding rib, other bone fragments began to appear. At first, it was difficult to distinguish bone from the alluvium, but the fine paintbrush magically exposed the black patina and striations of the bone pieces. As we continued, my son, Chris, exposed a new, larger piece, the end of another possible rib, and I found what was deemed to be some kind of phalange, roughly 3 inches long. This was very exciting, because technically we had actually discovered these particular pieces!

continued on page 68

Paleontologists *from page 66*

At this point, we learned about another very important part of the excavation process, that of mapping and logging each new find. Lorin produced a large lapboard with an extensively detailed grid map of the site. Both new bones were carefully drawn into the map in their corresponding locations. Each bone was then assigned a catalog number on a tracking document. This documentation is useful in the downstream analysis of the bones, particularly in attempts to articulate pieces; and when other museums borrow bones, this history of excavation provides important additional information. Copies of all mapping and logging documents are forwarded to the BLM for their records, as well.

Once logged and mapped, "my" phalange was bagged and removed from the site, so I could continued a more narrowly focused trenching around the rib. Chris was given the OK to carefully work on further exposing the large, yet unidentified bone he had found. Trenching is the process of excavating down around an in situ bone, leaving the bone elevated on a pedestal of stone 8 to 10 inches high, while still leaving about a 2-inch perimeter of matrix around the actual bone. This would allow for bone protection during the later stages of jacketing and removal.

Though I continued trenching with my hammer and screwdriver, Chris worked his new find with dental picks and very fine paintbrushes. Even with the slow, deliberate pace and extreme care he took, the bone was prone to cracking, but Lorin was not distressed. After Chris carefully brushed away dust and debris from the exposed area, Lorin applied a liberal dose of "squirt glue," known officially as VINAC. VINAC is a liquid adhesive with plastic beads dissolved in acetone. When this is applied to the bones, the acetone evaporates and the plastic hardens within the pores and cracks of the bone, essentially pulling the bone back together in a process known as consolidation. This helps stabilize fragile bones for trips from the quarry to the lab, and is a handy addition to the paleontological toolkit.

We were not the only ones having success. I noticed that the family to our right had also uncovered a new, previously hidden bone. The children, in particular, were rapt in the excitement of it all. They would definitely have a story to tell once they got back home to England! At one of the breaks, Lorin showed around a tooth that had been uncovered earlier that morning. It was unmistakable, black and sharp, but not all that large, and I could see how it could get swept away with the debris generated from the dig. It took a quick and sharp eye to pick it out from the dust.

continued on page 71

Paleontologists for a Day *from page 68*

Everyone was having fun and so absorbed in the work that our lunch breaks snuck up on us. I must admit the tasty picnic spread of various sandwiches, chips, fruit, and cookies went down well and disappeared quickly. Over the 30-minute break, we had an opportunity to get to know each other, especially the guests from across the Atlantic, all of whom marveled at the amazing expanse of the West. We all noted that we were beginning to feel the heat, already over 100 degrees and climbing. Even so, some of the group took advantage of another special feature of the quarry site, the "Trail through Time."

In 1985, a joint venture of the BLM and the museum established a 1.5 mile self-guided walking tour just to the east of the quarry and easily accessible from I-70. This "Trail through Time" teaches visitors about the existing ecosystem and geology of the location, as well as conditions that existed during the Jurassic period. The trail requires some moderate hiking to complete, but there are benches for frequent rest stops. Besides the spectacular views, the trail offers in situ exposures of a Camarasaurus and a Diplodocus skeleton encased in the sandstone. These are real skeletons, not reproductions, and deserve both admiration and respect — no souvenirs, please!

By now it was approaching 1 o'clock, and the museum team planned to work about another hour before packing it in for the day to avoid the extreme temperatures. Lorin reassigned tasks so that we could be exposed to yet another phase of excavation, jacketing. A cervical vertebra from an Apatosaurus had been completely trenched and was ready for removal from the site. In preparation for the jacketing, several yard-long, 6-inch-wide strips of burlap had been cut, rolled, and placed in water to soak. Lorin recruited three school-age girls to mix the plaster of Paris. Once they began, things had to move very quickly.

First, the exposed fossil was covered in a layer of wet paper towel to protect the surface of the bone. Once the plaster was the proper consistency, Chris was to ring out the rolls of wet burlap until they were barely damp. The burlap strips were very quickly unrolled, rolled in the plaster, and handed off to Lorin. He applied each plaster roll to the mound of bone and its pedestal of rock at various angles in repetitive layers. The necessity of clean and deep trenching became perfectly clear at this point.

Once all the burlap strips were used, the remainder of the plaster was liberally applied, ultimately forming a large white lump in the middle of the dig site. Since it would require half an hour for the plaster to cure and harden, everyone began cleaning up. The tools were gathered, sorted, and returned to their bins. The tents were broken down. To protect the exposed fossils against the elements, and to ensure their security, they were covered with strips of carpet, then a layer of loose dirt from the debris piles. This layer had to be removed each time the dig was revisited. I could see how each day's set-up would take about two hours prior to the participants coming to the site, and the museum volunteers were the diligent stewards of this process, as well.

Finally, the plaster had hardened and the bone was protected and ready for removal. With a few well placed pops at the base using a hammer and pry bar, the entire mound was freed with the bone safely encased inside. For the ride back to the museum, it was placed on a padded area of the truck bed and secured. Had the road back to the museum been more arduous or lengthy, the open base would also have been jacketed for extra protection. Even so, this relatively small bone has become a much larger, heavier package. One could see how really large bones such as long bones, skulls, and pelvises, once encased in plaster, could require heavy equipment to safely lift and remove them from a site. We had hoped to jacket and remove the rib we had finished trenching, but that was deferred to the following day, for another group of eager hunters to experience.

Everything was secured and the entire team loaded vans and trucks and headed back to the museum for the second half of the adventure. Back at the museum in Fruita, the group proceeded to a behind-the-scenes special treat: access into the preparation laboratory. Tables held several jacketed specimens ready for the next step, which actually seemed a lot like excavating all over again, except on a smaller, more focused scale. A cast saw is enlisted to open the plaster of fully jacketed specimens. The half-jacketed specimens are simply approached from the open base.

Once the host rock is exposed, the very tedious work of removing the bone is accomplished by using hand-sized pneumatic tools that scale off surrounding stone with accuracy. Once completely freed, the bones are cleaned and stabilized, if necessary, to preserve

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Paleontologists for a Day *from page 71*

them for research and/or display. When the bone is affirmatively identified, it is cataloged into the museum's already extensive collection, where museum guests may view it. Visitors to the museum who do not participate in the expeditions can still observe the inner workings of the preparation lab though large windows.

Taking in all that the museum offers is an equally important and educational part of the expedition. The Dinosaur Journey Museum focuses specifically on the paleontology of the Dinosaur Diamond region, with emphasis on sites in the very immediate vicinity. One can see the skeletons of a sauropod and the Mymoorapelta. Robotic reconstructions of "lifelike" dinosaurs simulate the behaviors of the owners of the bones. And there are numerous interactive exhibits for kids and adults. My favorite was actually one that targeted kids, an "excavate your own bones" area. Real Apatosaurus long bones covered with crushed walnut shells, which the kids could sweep away to expose the bone. The fact that three actual bones – not reproductions – are used is a testament to the volume of these bones that has been recovered in the Rabbit Valley region over the years.

Though sponsored by the Museum of Western Colorado, the Dinosaur Expedition experience has evolved through the convergence of several events and visionary people over the past two decades. Federal law prohibits the removal of dinosaur and other vertebrate fossils from public land without a permit. The U.S. Forest Service and the BLM are charged with the oversight of the public lands within which lie many buried fossils, and to prevent collection for the wrong reasons, certain criteria must be met before a site is permitted. The applicant must have either paleontological education or experience, and must designate a museum or university as a repository for the specimens so that the fossils recovered are available for ongoing research and reasonably accessible to the public, to whom they ultimately belong.

In 1985, a few years after the Mygatt-Moore site was originally discovered, a cooperative agreement between the BLM and the museum was established to manage and protect the fossil resources of the Rabbit Valley region. This model agreement served as the basis for future cooperative endeavors between the museum and the BLM. The Trail through Time is evidence of their joint efforts.

Then in 1987, Chris Mays, the founder of Dinamation International Corp. and maker of the robotic dinosaurs featured in the museum, approached the museum with a bold idea. He envisioned an opportunity for members of the general public to participate at an actual dinosaur quarry. Dinosaur Discovery Expeditions, as they were known then, began to make weekly ventures to the Mygatt-Moore Quarry, always with a paleontologist present. These early visits were very successful and well received by the public, and since then the program has expanded to offer one-day, three-day, or five-day packages. Over the ensuing years, the Dinosaur Expeditions program has hosted expeditions to such famous dinosaur locations as Como Bluff, Wyoming, Mexico, Argentina, and Mongolia.

Scuttlebutt among the scientific community has been periodically negative, with an attitude that the general public should not be involved in such delicate excavations. However over the years, the expeditions have made a positive contribution to the local and the broader paleontological community for several reasons. First, the exposure to the reality of professional fossil excavation may spur interest in young and old alike, possibly inspiring our next generation of amateur and professional fossil hunters. Second, the education imparted emphasizes reasons not to remove fossils on your own, and reinforces the importance of reporting possible finds to the appropriate organizations. Hopefully, this will dissuade scavenging, theft, or unintentional destruction of bones. Third, the revenue generated provides additional financial support for further site development. And fourth, even after just one day, all participants have a much better understanding of the fragility and tediousness of a proper excavation and all the work and conditions involved.

I commend the Museum of Western Colorado for offering this wonderful experience. This is the first field trip, mineral or fossil, that I have been on in a long time where I did not leave with a tangible sample. Nevertheless it was by far one of the most rewarding in terms of the fun experienced, people met, scenery absorbed, and knowledge gained. Dinosaur Expeditions at the Mygatt-Moore Quarry occur yearly in June, July and August. To find out more, call (888) 488-DINO or visit www.dinodigs.org. It is a must for anyone looking for a family-friendly learning experience tied to the excitement of dinosaurs. In Colorado, you really can be a paleontologist for a day!

Rock Science

Steve Voynick

Considering Cobalt

If asked to name a cobalt mineral, many collectors might come up with cobaltocalcite. But while it is perhaps the most familiar and visually appealing cobalt-containing mineral, cobaltocalcite is not a distinct mineral species. Cobaltocalcite is really a variety of calcite (calcium carbonate) containing small, variable amounts of cobalt which creates its characteristic, striking pink color.

Cobalt is an element that forms very few familiar minerals. Most cobalt minerals are a silvery white to grayish black, with occasional hints of red or pink. Cobalt associates mineralogically and most commonly combines with the elements iron, nickel, arsenic, and sulfur. Its ores include cobaltite, a cobalt sulfarsenide known as 'cobalt glance'; skutterudite and smaltite, both members of a cobalt-nickel arsenide solid-solution series; linnaeite, a cobalt sulfide; glaucodot, a cobalt iron sulfarsenide; and erythrite, a bright pink, hydrous cobalt arsenate called 'cobalt bloom'.

Cobalt compounds have been known since antiquity. By 2500 B.C. cobalt oxide prepared by heating such secondary cobalt minerals as erythrite was used to impart a deep blue color to glass. But as late as the 17th century, cobalt itself was known only as a mysterious component of silver ores from the Erzgebirge Mountains (on the present border of Germany and the Czech Republic) that interfered with silver smelting. Miners called it "kobold," a derogatory term meaning "goblin" or "evil spirit" and referring to supposed dwarfs who dwelt in the earth and guarded precious-metal ores. German chemist George Brandt finally isolated the strange metal in 1735; in 1785 it was identified as a new element and named "cobalt," after the Middle German kobold.

Cobalt is a hard, brittle metal with physical properties similar to those of iron and nickel. Like those metals, cobalt is ferromagnetic, but retains its magnetic properties at much higher temperatures. Cobalt also has an unusually high melting point of 2,729 degrees F. Although sometimes thought of as rare, cobalt ranks 33rd in crustal abundance and is a bit more common than lead. But because of its uniform crustal distribution, cobalt rarely occurs in concentrations rich enough to mine.

Before the 20th century, only a few cobalt oxide and silicate compounds served as blue pigments in paints and glass. But by 1910, metallurgists had found that cobalt had superb alloying properties that significantly enhanced the wear, corrosion, and thermal resistance of steel. The first uses of metallic cobalt were in high-speed cutting tools and dies. Only a few hundred tons of cobalt were then mined each year, but production increased rapidly.

Cobalt, which is also associated mineralogically with copper and silver, has lent its name to two former mining areas. Cobalt, Idaho, is the site of the Blackbird Mine, which exploited a large cobalt-copper deposit until 1982. In Canada, the famed silver mining district of Cobalt, Ontario, was named for its surface occurrences of pink erythrite cobalt bloom which led prospectors to nearby silver deposits.

In the 1930s, American and Japanese metallurgists simultaneously developed "alnico" alloys consisting primarily of aluminum (Al), nickel (Ni), and cobalt (Co), along with lesser amounts of copper, iron, and titanium. With their very high magnetic susceptibility, or ability to magnetize, alnico alloys have many industrial applications.

In the 1950s, researchers bombarded cobalt with neutrons to produce cobalt-60, a highly radioactive isotope that is still the preferred source of intense gamma radiation for many industrial and medical uses. During that time, researchers also identified cobalt as the essential elemental component of vitamin B-12.

Some 40,000 metric tonnes of cobalt are now mined each year. Most cobalt is recovered as a byproduct of mining and processing nickel, copper, silver, platinum group metals, and zinc ores. The world's only remaining primary cobalt mine is located in Morocco. The leading sources of cobalt are the Democratic Republic of Congo (formerly Zaire), followed by Zambia, Canada, Australia, and Russia. Refined cobalt metal sells for about $10 per pound.

Although its minerals remain largely unfamiliar and are found in few collections, cobalt, along with its compounds and isotopes, plays a big part in our everyday lives.

The Beryl Family

This Species Has Many Lovely Gems

Story by Kenneth H. Rohn / Photos by Jeff Scovil

When beryl is mentioned, I believe that the vast majority of gem admirers' thoughts turn to emerald. For some reason, probably its beautiful green coloration, emerald is one of the most sought after and highly prized gemstones. It has been a favorite of royalty for centuries. It happens to be the birthstone for May. The name "beryl" stems from the Greek word berylos, meaning "a green stone."

Beryl, beryllium aluminum silicate ($Be_3Al_2Si_6O_{18}$), has several species in the family. The hardness of beryl may be anywhere from 7.5 to 8 on the Mohs scale. This makes it an excellent, wear-resistant gem for jewelry. The cleavage is conchoidal and often indistinct. It may cleave only in areas related to foreign inclusions along the basal plane in the mineral. All beryl species are vitreous, transparent to translucent, and striated the length of the crystal. This trait is just the opposite of quartz, in which the striations will be crosswise. The specific gravity of all species of gem quality may vary between 2.65 and 2.85.

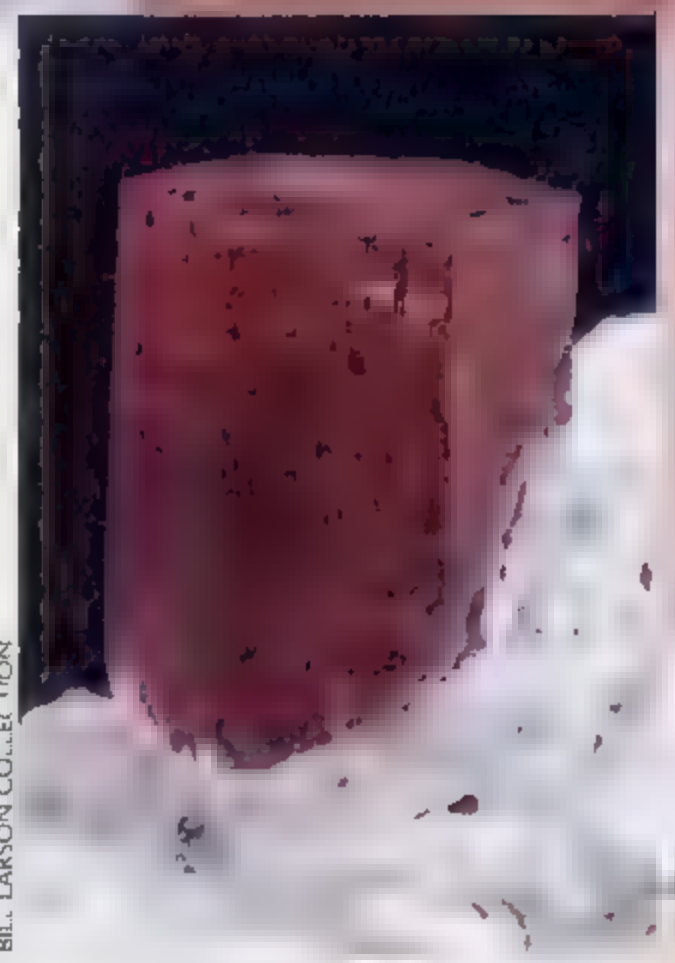
Beryl's basic structure is a simple hexagonal habit, with a plain six-sided crystal that is often flat on the end, as if the tip or point had been purposely cut off. At times, it may be found with an intricate rhombohedron. Due to its hardness, beryl cannot be tested by using a streak plate. Any mineral Mohs 6.5 or harder must be

BILL LARSON COLLECTION

Aquamarine, colored by traces of ferric oxide, is subject to many imperfections such as crazing and inclusions

HOUSTON MUSEUM OF NATURAL SCIENCE SPECIMEN

Morganite's pink to lilac coloration is caused by traces of lithium.



BILL LARSON COLLECTION

Rich red beryl is found only in small crystals in one or two localities, including the Wah Wah Mountains of Utah.

ested by grinding a small fragment of he stone to a fine powder and spreading it on a white background. In all species of beryl, the streak is colorless.

There really is no correlation between the size of one beryl species and another. They may be found as tiny, jewellike crystals that seem to have been cut by a lapidary or in huge crystals. The smaller crystals usually yield near-flawless gems. At other times, beryl crystals have much fracturing and deep etching. Wherever this mineral is found, it can yield ore-grade massive beryllium as well as some fine gem-grade stones.

Beryl is a doubly refractive mineral, which often gives the various species a pronounced two-color change. Dichroism is quite prominent in all species except golden beryl, which doesn't show much change when examined through a dichroscope. This color change may be subtle in one stone and more pronounced in another. A stone may be light blue when viewed from one face and almost colorless when seen from another. A pink stone of no real outstanding coloration from one direction may display a most dazzling brilliant pink when viewed from another window or facet. This is due to the double refraction in the hexagonal habit of this stone. This phenomenon always causes some problems for the lapidary, and a crystal must be examined carefully before cutting.

All members of the beryl family are almost exclusively products of pegmatites. Emerald may sometimes be found in other environments, but this is an exception. All beryl species respond readily to high-heat treatment, which often turns a bland, off-color stone into a beautiful pink or blue jewel.

Beryl will be found in pegmatite gem pockets along with several other species. A pegmatite pocket may contain quartz, tourmaline and feldspar crystals that have grown from the ceiling. The core of said pocket will usually contain beryl crystals of one species or another, sometimes at the bottom next to the line rock of the cavity. The crystals floating in the cavity are sometimes doubly terminated. The pocket may often contain loose, deformed quartz crystals, mica books, myriad crumbled mica particles, and tourmaline, some doubly terminated, all cemented into one mass by a white to yellow and/or brown clay substance.

Beryl is found in many localities in the United States. Mount Antero, in Chaffee County, Colorado, has continuously produced valuable aquamarine crystals. The New England states, particularly Maine, have also produced vast quantities of this mineral. North Carolina is a big producer, and has been for better than 150 years. Who can forget the beautiful aquamarine and outstanding morganite crystals from the pegmatites of San Diego County, California? Light-green beryl is mined, along with scheelite, in pegmatites in Pershing County, Nevada, and South Dakota has produced its share of beryl.

I recently had the opportunity to investigate a massive pegmatite dike while on a field trip in South Dakota's Black Hills with fellow members of the Manitoba Mineral Society. It was at the Dan Patch Mine, located near Keystone in Pennington County. The mine was named for the owners' racehorse, Dan Patch, and had been bought with prize money won by the famous horse. The pegmatite had been stripped and its beryllium content mined out decades before, leaving a shaft and drifts in the solid rock of the mountain. I believe some lithium was also mined there and at other localities in the Black Hills during World War II, when it was in great demand for strengthening spring steel and hardening copper.

COLLECTOR'S EDGE SPECIMEN

Mount Antero, in Chaffee County, Colorado, has continuously produced valuable aquamarine crystals.

The Dan Patch pegmatite dike was huge. It consisted of an extremely deep near vertical shaft many yards in diameter. One can only guess at its depth because it is now filled with water to the existing table. As I recall, the members didn't find any gem-grade beryl, and neither did I. If the shaft was dry and there was a way to climb down into that abyss, it's possible that some crystals might be found. The Dan Patch pegmatite has yielded some gem-quality aquamarine in the past.

The most prominent of the beryl gemstones is the pleasing grassy-green emerald. In contrast, the equally beautiful aquamarine is often the passed-over and neglected sister. This stone is the color of blue-green seawater, at times more blue than green. During the reign of the Romans, aquamarine was worn as a charm while on sea voyages and was believed to ward off seasickness.

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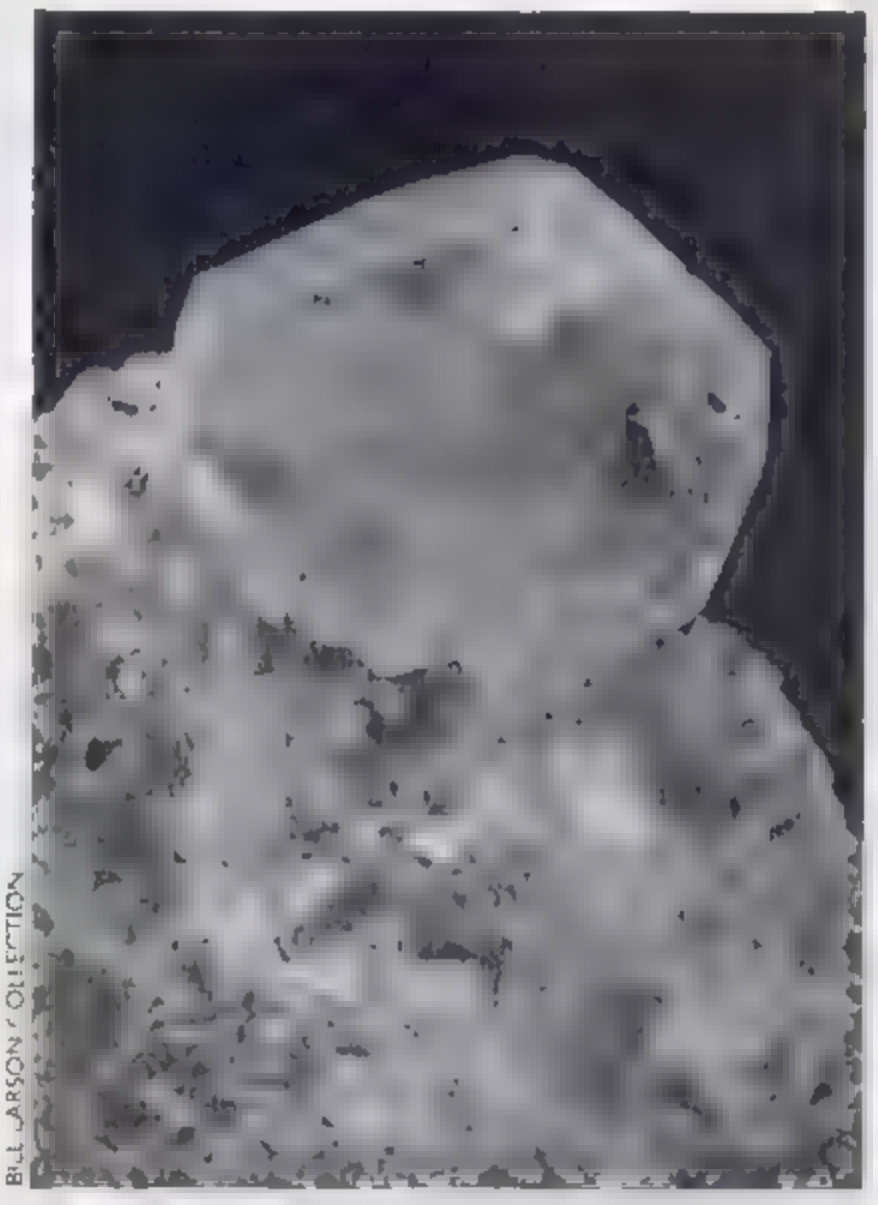
The price of a perfectly faceted emerald can often go much higher than that of a diamond of equal size. One of the reasons for this is that most emerald crystals are heavily flawed. Quite often, emeralds are found fractured from extreme pressure, to the point where only a group of small faceted gems may be gained from one stone. When an area suitable for cutting does exist in a crystal, the finished gem demands a premium price.

Emeralds, as well as other beryl species, are often flawed with myriad minuscule inclusions. These inclusions, or phantoms, are called, "gardens." They will usually be in the form of tiny hollow tubes and/or hairs of a foreign mineral, which cause the stone to look cloudy and discolored, sometimes to the point of being unfit for faceting. Another stone in the same pocket may have several areas suitable for cutting. It all depends upon how conditions were at the time of formation. Color is also an important factor in a gemstone. Emeralds do not always have a continuous shade of color from one end of the column to the other. There may be near-colorless zones in the same stone.

One way to differentiate between a man-made faceted emerald and a natural stone is that the former will always be flawless, whereas the natural stone will have inclusions, even if they can only be seen with high magnification. The color of rich green emerald is attributed to the presence of chromic oxide. I have one emerald cabinet specimen. It actually looks nothing like my faceted gems except for its deep green color, but I wouldn't part with it.

A few years ago, I had the opportunity to visit two emerald mines in North Carolina. It was during a cold snap in February, and the slippery condition of those mountain roads rivaled that of any in Minnesota. It was snowing the day my wife, Lorraine, and I arrived at one mine in the mountains near the community of Little Switzerland. We had traveled east over the Blue Ridge Mountains and were forced to bypass Great Smoky Mountains National Park, which we had looked forward to seeing, due to impassable road conditions in the park.

As luck would have it, the mine was closed for the winter. I believe it was called The Crab Tree at that time. The massive drift carved into the solid rock mountainside was impressive. An 18-wheeler could have easily been driven into it. I have no knowledge whether that mine is actually working today, or whether the owners allow fee digging. At one time, if my memory serves me correctly, they did allow collecting on the waste dump. Some investigating, if one is in that area during warm weather, might prove productive.



BILL LARSON / COLLECTION

This fine morganite crystal came from the Tourmaline Queen Mine near Pala, California.

The other mine we visited was near the town of Hiddenite, North Carolina. This area has been big news most recently when several pegmatites were uncovered, exposing many fine emerald crystals.

My experiences at Hiddenite were not what I'd call spectacular. We met the manager at one fee mine, and were given permission to dig in a pit in a heavily wooded, rocky hilltop on the property. The pit was excavated to about 6 feet deep, 40 feet long, and 20 feet wide. We spent the better part of the day digging in that pit. The locals were bundled up in rather heavy winter clothing, to ward off the cold. Being acclimatized to bitter, often sub-zero conditions at this time of year, we Minnesotans felt comfortable in light jackets.

We were given a screen, shovels, and a pick, and were left to our own devices. The sun felt warm and it wasn't long before I took off my coat and worked in my shirtsleeves. We had great enthusiasm that day, with the thought that the next screening might produce an emerald. As I worked, I saw visions of a gem pocket being exposed at any time. We screened several 5-gallon buckets of rusty, red-tinted dirt before lunchtime. It was hard digging. The pit was a conglomeration of rocks of all sizes, gravel contaminated with tree roots, leaves, mica particles, and clay. It was dirty, and we were a mess.

After working in that pit for the better part of the morning, we finally took a lunch break. Later that afternoon, we managed to collect some well-formed, but small, wine-colored rutile crystals and one black tourmaline (schorl) crystal. We were told that this was an indicator that emeralds might be present. They weren't. Rutile, if found in a reasonable size, can be cut into a gemstone. It also is the principal ore of titanium and is used as a ceramic glaze.

It is my belief that the area we were digging in was too shallow. The pegmatites of the recent finds were discovered at 30 feet and deeper. We may have been right above, but quite out of reach of, some valuable crystals. It was an enjoyable day, and the memory of that experience lingers despite the end result.

Aquamarine, the birthstone for October, deserves a higher status in this family. No doubt about it, it's my favorite of the beryls. The interesting thing about this stone is that it can be usually purchased for a fraction of the price of an emerald of equal size. It can often be found in flawless, beautifully formed crystals in pegmatite gem pockets. But alas, as with all the other beryls, it is also subject to many imperfections such as crazing and inclusions. The color of aquamarine is due to traces of ferric oxide.

I have two cabinet specimens of aquamarine in my collection. They aren't very big – about ½ inch in diameter – they're heavily flawed, and they look like blue-green ice cubes. I also have faceted beryl gems in my collection, including aquamarine, morganite, and golden beryl, they're all in the same family, yet so different from one another.

continued on page 84

The Beryl Family *from page 82*

Morganite, named for New York banker J.P. Morgan, an avid collector of American gemstones, ranges from pink to lilac, with several shades and variations of these colors. This coloration is caused by traces of lithium, although other crystals in the same lithia pocket may have different colors. So the question arises: Why did lithium color the morganite and not the other beryl crystals in that pocket? I'd guess the answer is because they formed at different times.

Morganite is found in short, tabular crystals, whereas aquamarine will form a column many times longer than its diameter. Emerald is a compromise somewhere between these two crystal shapes. Quite often, simply to avoid confusion, a variety of pink, yellow-pink, and orange crystals may simply fall under the nomenclature of morganite.

Coloration in all beryl crystals is caused by the partial replacement of beryllium with sodium, lithium and cesium, which, of course, has nothing to do with dichroism.

Golden beryl and heliodor contain the element uranium oxide (plus ferric oxide in heliodor), which gives them that magnificent golden coloration. However heliodor is often more brown than golden. The name heliodor, as derived from Greek words roughly translated as "a gift of sunlight." Heliodor is found in Africa, among other places.

Strangely enough, beryl crystals may, at times, be completely enclosed in massive quartz or feldspar crystals. These are poorly developed, due to extremely high pressure. They may be actually crushed and fractured beyond the possibility of cutting any gems from them. Only when a tip of the crystal is exposed in these quartz bodies will the beryl be of gem quality and suitable for cutting small stones. Quite often, the crystal tips will be perfectly formed with glassy, smooth, etched faces.

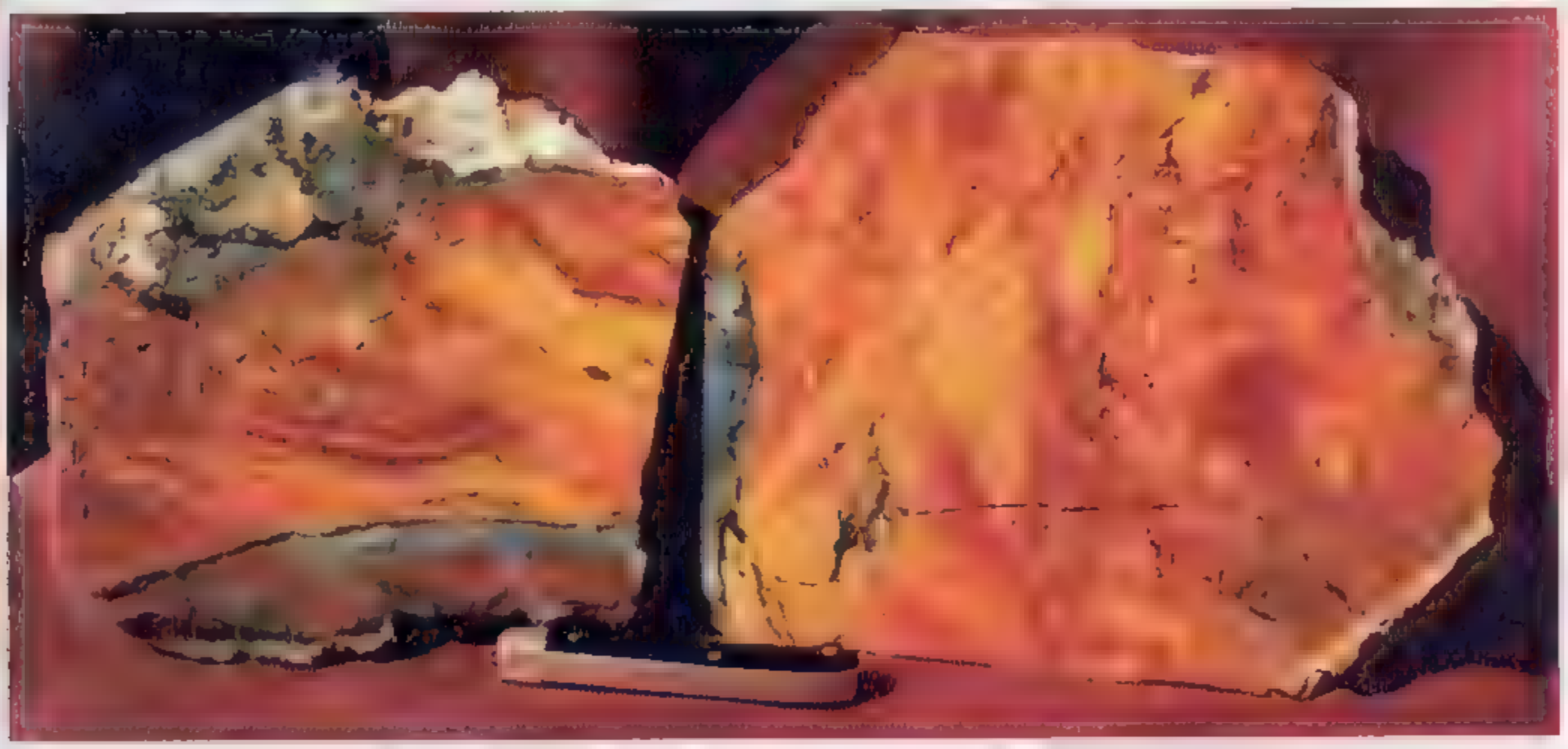
Goshenite is not very well known, but it deserves mention here. It is a colorless, often water-clear variety named after Goshen, Massachusetts, the locality in which it was first discovered. Due to its clear nature, dichroism is absent. Goshenite and morganite are quite likely to be found in lithia pockets in pegmatites.

Many factors have played a part in the formation of beryl, as with all gem species. Nature often hasn't finished the job, and we find incomplete, sometimes deeply etched and cloaded crystals that might, under better conditions, have become magnificent gems. At other times, a brilliant crystal of perfect structure will be discovered. But after all is said and done, we are most fortunate to have the opportunity and privilege to be able to go out into the field and discover things of such timeless beauty.

Collecting in WESTERN OREGON

Gems Abound in Mountains, Streams and Valleys

Story and Photos by Curtis L. Handy



I call this strongly colored material, which I collected from Scott Mountain, Oregon, Indian Autumn jasper

"I usually park here," Don said. "We'll follow the trail over there through the brush and timber to the creek." This was the start of an excellent field trip for Don Reed and me, searching for petrified wood. The location was Western Oregon, in an area southwest of Sweet Home, not far from the state capital of Salem.

This part of Oregon contains much fossil wood known for its excellent quality. Nearby towns include Lebanon, Stayton, Scio, and Sweet Home. Localities such as Franklin Butte, Rogers Mountain, and Crabtree Creek sport an abundance of collectible wood. Much of this property is private, but a good amount can be accessed via Forest Service and BLM roads. Logging roads are also numerous. Years back, a number of fee-collecting sites were in operation, but they no longer exist.

With buckets and tools in hand, Don and I crossed the small gravel road and entered the trail leading into the timber and toward the creek. After a walk of a quarter mile or so, we could see the creek ahead in a sloping draw. The bank on our side of the stream was about 4 feet high. Beyond, a large hillside loomed through the trees.

I said, "Don, this is really a nice, peaceful spot." He replied, "Lots of wood here, too! Let's walk up here a ways to this big log—got some good stuff last time we dug there."

Petrified wood species of many kinds are found here, conifers, cedars and firs in particular. There are also hardwoods, including oaks, maples, sycamore, and elms. More than 70 distinct species, both ancient and modern, have been identified from the area surrounding Sweet Home and the little community of Holley.

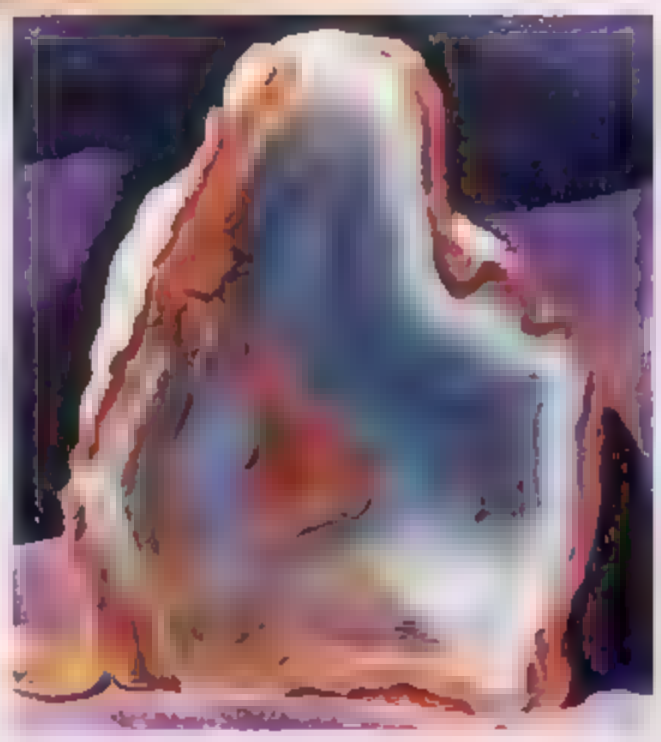
A mattox is especially useful for digging here. This tool has a pick on one end and a blade about 4 inches wide on the other. It works well in the soft forest soil, and is useful for pulling the dirt back into the holes or trenches to cover them back up.

A ringing clink sounded where Don was working. "Not bad, about a 5-pounder," Don exclaimed with a big smile as he brushed away the dirt from a nice, solid piece of wood. And so the time passed as we grubbed along above our private little creek. There were many more chunks of "native" stone than pieces of fossil wood. However, piece after piece of silicified wood, in a variety of shapes and colors, was added methodically to our buckets. There were even some that were too big for a bucket!

After a while the creek's water became irresistible and I began a wading search upstream. The results were excellent! I

discovered pieces of wood with just their noses poked above the gravelly bottom and more wood hiding in undercuts in the bank, as well as some lying blatantly visible in the cool, clear water. The orange-brown ones really stood out, others in shades of grays, browns and blacks required a careful look to spot. A trip downstream seemed in order, so I stashed the keepers along the bank to pick up later.

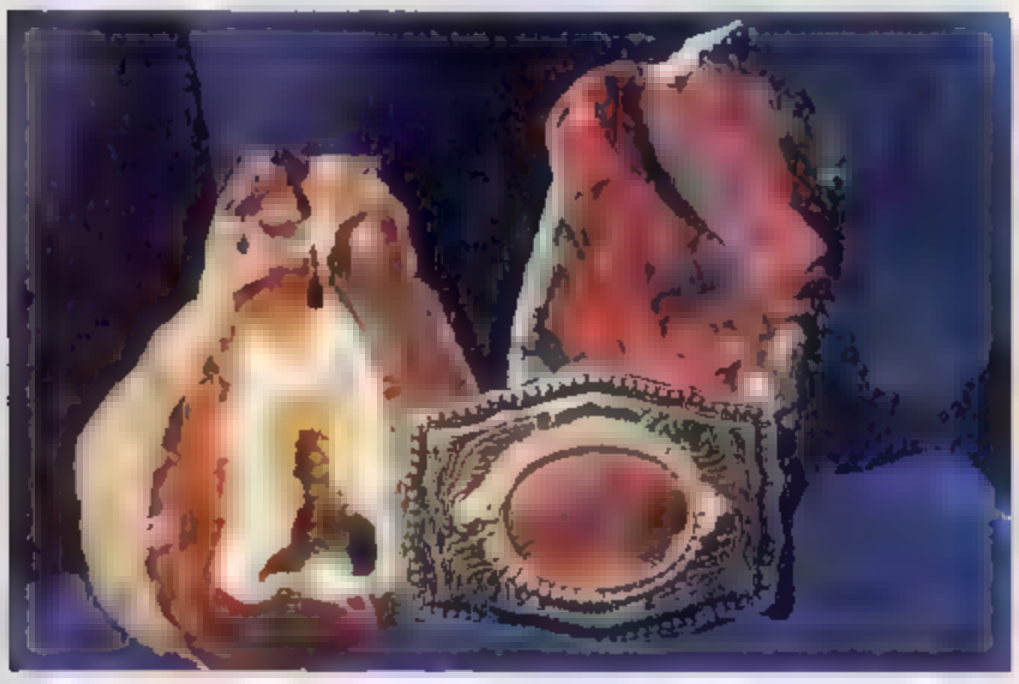
As I arrived downstream at Don's location, he asked, "Find anything?" I replied, "Yes, some pretty nice pieces. I'm headed on downstream to see what I can see." This proved productive, too. There was a very interesting bench above a bend in the creek that looked promising. Don and I talked it over when I returned to where he was digging and we decided to relocate to the bench. It proved to be a good choice. I was finding good-sized chunks of wood, but lucky Don was finding limbs and



Darren Jordan collected this prize agate near Holley in Western Oregon.

reads, "The most notable petrified forest area in Western Oregon is the region around the little community of Sweet Home .. the denuded fossil trees [were] found standing in the vertical position and are approximately 50 million years in age . standing in the midst of present-day Douglas fir forest no more than 200 years old . the area of vertical standing stumps is not an isolated one, but extends over a considerable area . In one area of only a few acres twenty large stumps were noted . Scattered about this area are [were] many tons of large and small petrified logs and a great amount of fragmentary material."

Not surprisingly, after nearly 50 years, much of the area's wood has been collected, however, many tons remain and the general area Dr. Dake spoke of is a popular one for collectors. Remember, much previously accessible and is now private and permission is needed to collect on it. The gravels of the Calapooya River, which runs through the area, still produce wood, as well as jasper and agate. Also mentioned in *Northwest Gem Trails* is an area near my home in Roseburg, Oregon. "In Douglas County, the various tributaries of the Umpqua River have produced many fine gem materials, including agate, iris agate,



This carnelian agate (left) and jasp-agate were collected near the top of Quartz Mountain, above Glide, Oregon.

Carnelian agate, stained red-orange by iron, is found at many locations in Western Oregon.

small rounds - even though we were digging practically side by side. "Wanna trade sides?" I asked. He answered with a subtle side-to-side head movement, and kept digging.

Too soon, it was time to re-sort our finds and hike back out to the pickup. Digging had been good, but the load was heavy, even after sorting. We picked our way through the brushy trail, encumbered by our hard-to-carry tools and bulging buckets. When the road and rig came into view, it was a welcome sight.

Many places similar to this one exist in Western Oregon. The trick is to find them. As mentioned, public fee digs were once common in the area, but no more. Other sites are usually known only to a few locals and/or clubs. Directions to specific sites are far too cumbersome to deal with. But sites can be found by those who really make the effort.

A vintage, but tantalizing, description of Oregon's petrified wood from H.C. Dake's out-of-print book *Northwest Gem Trails*, 2nd edition (J.D. Sampson, 1956)

Jasper nodules collected from a stormy winter beach near Bandon, Oregon, show the bright colors of iron oxides.

moss agate, plasma, jasper, bloodstone, and carnelian." Many of which, I'm happy to say, I've collected!

Oregon's distinctive shape, as depicted on today's maps, would appear much different if not for ancient geologic forces. They continue even today and have resulted in an Oregon divided into east and west sections by the volcanic Cascade mountain range: desert to the east, and hills and valleys to the west. Oregon's present coastline runs nearly north and south, in eons past, it angled from the lower southwest corner of the state to the Wallowa Mountains in the upper northeast corner. Seashells and fossils embedded in high peaks attest that it was once a coastal range. The old sea retreated as the forces of nature heaved the sea-covered land upward, resulting in the Oregon of today. This process deposited plenty of rock treasures. Collecting in Western Oregon yields an overwhelming multitude of gemstones!

continued on next page

Collecting in Western Oregon *from page 89*

Zine Creek, in the watershed of the South River above Canyonville and Tiller is a popular area for collecting a variety of agate, jasper, wood and other materials. Although there are no developed dig sites, material can be found all through the Zine Creek drainage. Forest Service and BLM offices usually have good maps that show the location of the many roads that crisscross the area. Like gold, much of Western Oregon's rock is where you find it. A bonus for traveling through the country is the beautiful mountains and scenic vistas.

Another site is Cow Creek in the Riddle area, which encompasses the old Hanna Nickel Mine. I have a good supply of what locals call Cow Creek jade (serpentinemidas raset), dug from a hillside mining claim above the creek. Actinolite, tremolite and, of course, nickel dot the area and seem present in many rocks.

Gold, too, is found in Cow Creek, as well as in Quines Creek, near the community of Azalea. Cow Creek's confluence into the South Umpqua River is at Canyonville, which was the site of a gold strike during pioneer days. There are many claims in the area today.

During the spring of 2004, a group of us, including "Digger Don" Reed, wound our way up and along Little River, a tributary of the North Umpqua River. Our destination was a carnelian agate collecting site on Quartz Mountain in the foothills of the Western Cascades, some 4,500 feet above the valley floor. We bumped our way over a barely discernible, twisting track and arrived in a glade, once logged and now rather meadowlike. Large Douglas fir stumps stood here and there, some were uprooted blowdowns. Chunks of carnelian could be collected from the exposed root systems by just digging the dirt away. The site is not a "secret" one and has been collected from over the years. It is, however, difficult to find. In years past, much material was found above ground as float. But now, you must dig 1 foot to 4 feet to find the agate. Various colors of jasper are also found along with the carnelian.

We each picked a likely-looking spot and put picks and shovels to soil. Don began digging under a large, rotten log and suggested I shovel out a previously dug place and extend it. Digging in the moist spring soil with a mattox was not too difficult, and soon I was into new soil. Before long, I heard the ring of agate on the pick's blade. Slowly, with the pick's sharp end, I unearthed an excellent dark-red, 5-pound piece of carnelian.

Don's progress was impressive, but was yielding little, so the dirt went back into the hole and he began a new dig just up the hill from me. We found many basaltic rock chunks as we dug. At first, each seemed like it would be the big agate we were hoping for. A few years ago, a 65-pound piece was found, but when scraped free of mud and dirt, proved otherwise. However, agate appeared often enough to keep us digging.

Don's new location began to pay off with numerous pieces. Some pieces were small, some bigger and some up to 15 pounds. My bucket was showing signs of filling with a variety of sizes and types of carnelian (light and dark red, orange, botryoidal, etc.). Periodically, large and small pieces of jasper appeared, some of which were good quality and worth keeping. (I've since made very nice cabs and pendants of the red and yellow and the black-and-orange jasper.)

The weather was ideal, clear and sunny with a bright-blue sky. The mountain air was clean, clear and fresh. The solitude of the mountain was interrupted only by our digging and chatter. During "breathers," we inspected and compared our finds and contemplated where to dig next. One of the group, Rob, moved to a large stump and found the big one of the day, about 20 pounds, with nice color and form. It just goes to prove the more you dig, the more you find!

We made a full day of digging and back filling. By 5 p.m., we were loaded up with the day's bounty and headed back home, where we nosed out our efforts: a collection of a nice variety of red carnelian agate and some jasper. This dig site produces several kinds of carnelian, some with druzy quartz, others with crystal pockets and botryoidal forms, as well as many shades of colors in many different shapes and patterns. Layering and concentric banding are also prevalent.

For those not inclined to bushwhack through the wilderness, collecting on the Oregon Coast offers wide-open spaces and stretches of sandy beaches. These are often strewn with all manner of agate, jaspers, and petrified wood, as well as beach-combing stuff like fossils and driftwood. Collecting on Oregon's scenic beaches is always fun, and usually rewarding, for the rockhound.

continued on page 92

Collecting in Western Oregon *from page 90*

I've had good luck on the beaches in the Bandon area, Seven Devils Wayside Beach in particular. A trip three years ago during a very cold, stormy day with wind-driven rain netted several buckets of really excellent, colorful jasper. There were not many agates, but a good amount of black and brown petrified myrtle wood, both large and small pieces. The jasper was just the right size for tumbling, up to walnut size. It is found in all colors, banded, brecciated, and mixed with agate. The colors are very bright, and on this day there was much to choose from.

On this particular day, there were several beds of gravel stretching for hundreds of yards up and down the beach, some 100 feet wide! A friend and I bent our shoulders to the wind and rain and tracked slowly back and forth with bucket in hand. As the haul became heavier, we parked the buckets and searched in a circular pattern around them. We spent several hours exploring among the driftlogs and creek flows, collecting from seawall to surf line.

Other large pieces of subtly banded rock, perhaps sedimentary chert or metaquartzite, populated the beach, as well. They were very rounded and smooth, and many weighed up to about 10 pounds. Most all were somewhat flattened by the action of the rolling surf and sand, Mother Nature's tumbler. I collected several for landscaping purposes.

Even with the cold, stinging weather, it was a great and enjoyable trip. Back home, after six weeks in the tumblers, the two 12-pound loads of jasper, wood, and agate polished up bright, smooth, and very shiny.

Early spring, after storms, is usually the best time to search the shorelines. The turbulent action of storms often removes sand from the beaches and reveals beds of gemstone gravel hidden beneath. Timing is important, as the weather calms, the deposition of sand begins. Soon, several feet or more pile up on top of the rock, leaving nothing but miles and miles of barren beach. Consult a tide book for low-tide times, especially "minus" ones, as more beach will be exposed and you'll have better luck. High tides can cover the beaches and the rock you are hoping to find.

A second trip the following year was also a good one. The weather was better, and this time we brought a wheelbarrow to get the heavy buckets of rock back to the car. A friend on the coast had called me to say there was even more gravel exposed at the beach than during our first trip. I arrived a week after his call to find some rock on the beach. Calm waters after the storm had done its work, and much of the gravel lay buried under tons of sand! However, the logs and woody debris left at the high-tide line near the seawall had captured a good amount of rock. By searching there, I was able to collect an ample amount of colorful jasper, as well as a few good agates and myrtle wood.

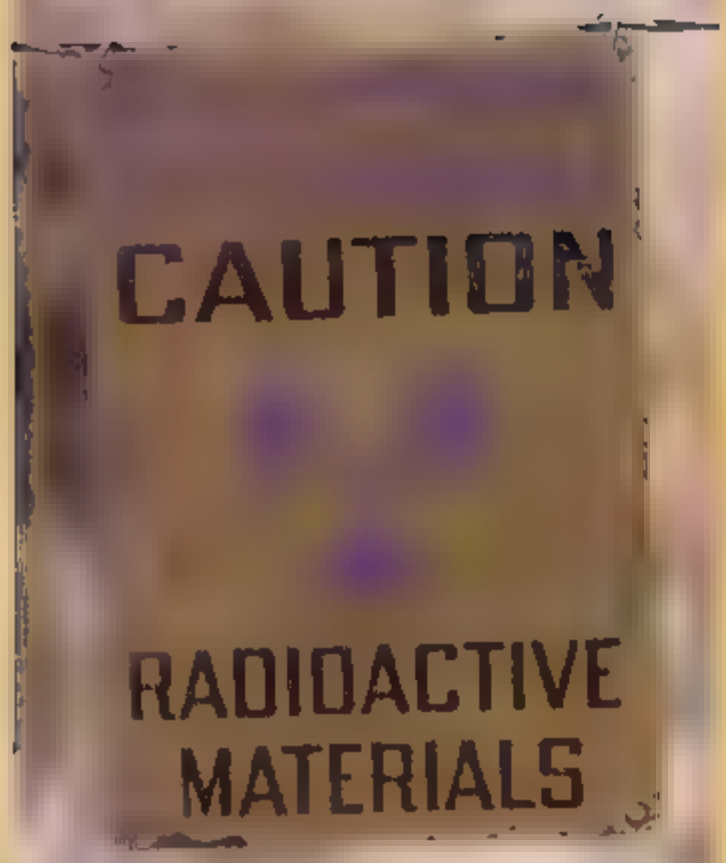
Whiskey Run Beach, a little farther south towards Bandon also provides excellent collecting. These beaches, however, are often sanded in. They also seem to contain more agate than Seven Devils, if you can catch them uncovered. Whiskey Run, by the way, received its name during the mid-1800s during a gold rush to the area. It seems an enterprising fellow planning to sell whiskey to the miners sampled a bit too much of his product and ended up spilling barrels of it into the creek that emptied onto the beach.

Interstate 5 provides easy access to Western Oregon. It runs the full north-south length of the state. Many other roads branch off in all directions. Good information and directions are a necessity for a successful collecting trip. Field guides are but one source; rock shops, and local residents and clubs are others that could be useful. There are thousands of miles of all-weather roads through the hills and mountains that access likely spots to explore and collect.

Spring through fall is the best time for collecting trips. Winter snows will cover the higher-elevation country, while the lower elevations will typically be muddy with rain. Our local group of rockhounds anxiously awaits the warmer spring weather to clear the snowbound road to one of our dig sites at over 4,000 feet in elevation. By summer, the ground is hard and dry and tough to dig in. In springtime the soils are still soft and moist.

I'm fortunate to live and collect in one of the nation's best rockhounding states. Quality rock is amazingly abundant here. Oregon's reputation for premier collecting is well deserved. Fire up your computer's search engine for more collecting info, a few key words will pull up scores of sites. Several Oregon state sites can be of much help, too. A well planned trip should produce excellent results.

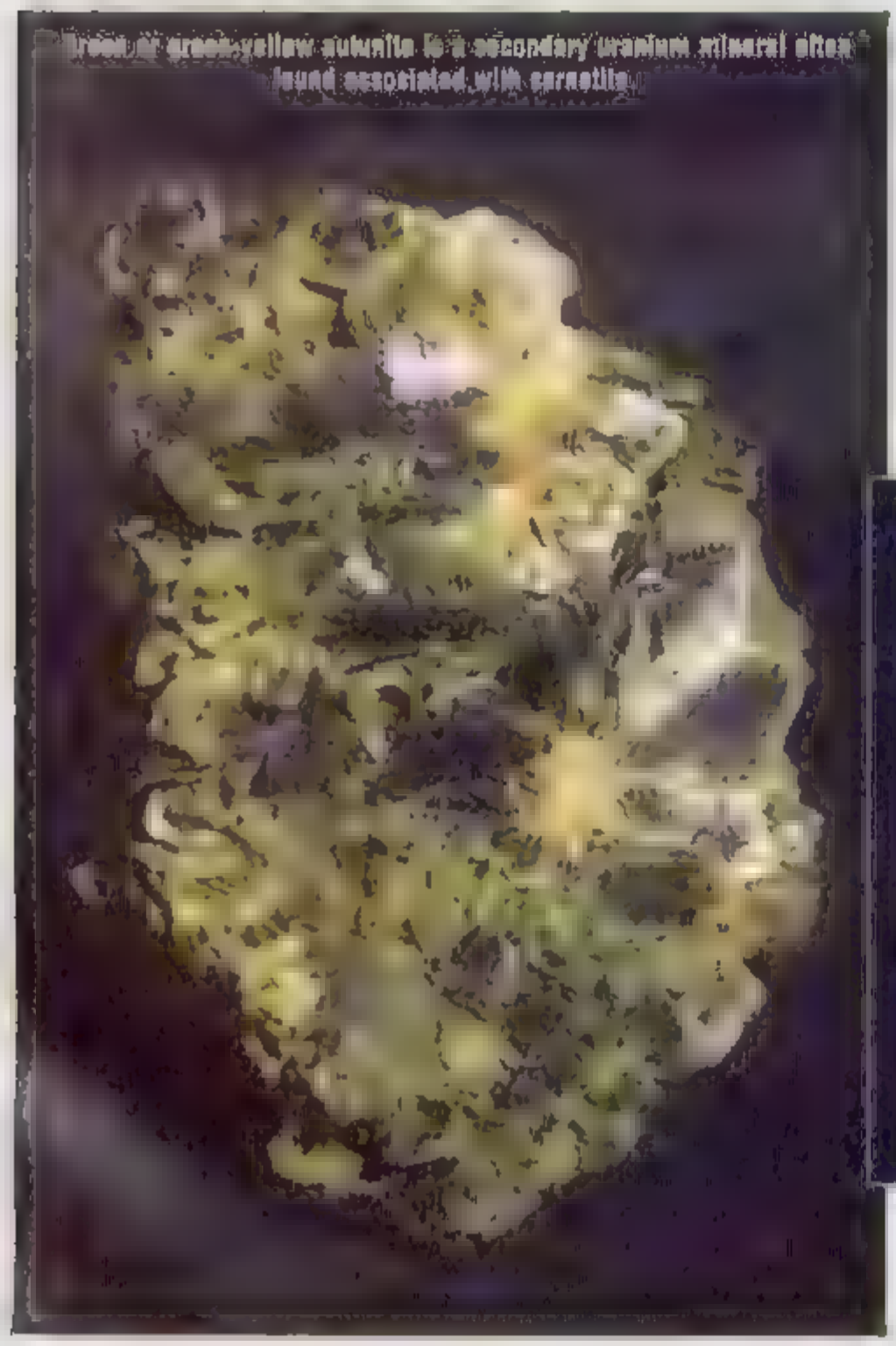
Whether you plan to collect fossil wood from the famous Lebanon area, beach agates along the Oregon coast, or agates, jaspers and wood from the easily accessed rivers, creeks, and gravel bars, be sure and bring plenty of buckets. If you've done your homework, you'll need them! Oregon's mountains, streams, hills, valleys, and seashore produce gems galore!



The Uravan Mineral Belt

Story and Photos by Steve Voynick

Renewed Mining Is a Boon to Collectors

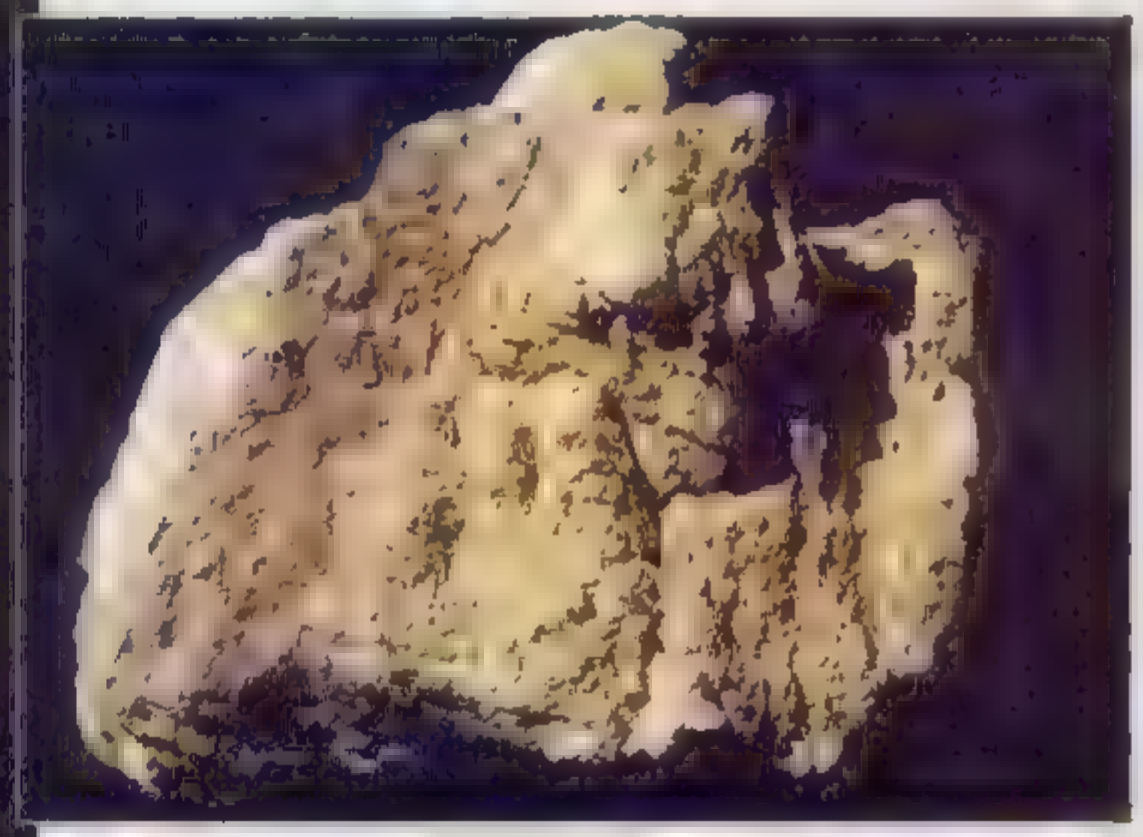


The Uravan Mineral Belt, a 70-mile-long, crescent-shaped zone of mineralized sandstone sprawled across southwestern Colorado and adjacent Utah, is currently one of the nation's hottest pieces of mineral real estate. Right now, the Uravan's 2,500 square miles of rugged, red-and-yellow sandstone cliffs and plateaus are echoing with the unmistakable sounds of a mineral rush: the hum of four-wheel-drive vehicles, the clatter of core-drill rigs, the drone of geophysical-survey aircraft, and the steady thump-thump-thump of hammers on claim stakes.

In just the last 12 months, prospectors and exploration geologists have staked some 10,000 mineral claims, all of them for uranium, the price of which has recently jumped from $5 to $30 per pound. And with many uranium-market analysts projecting $100-per-pound prices not far down the line, this rush is quickly turning into a bona fide mining boom.

The Uravan Mineral Belt (the name is an acronym derived from *ura*nium and *va*nadium) is one of the nation's more unusual mining regions. Although the Uravan is synonymous with uranium, it has also yielded two other mineral products: radium and vanadium. Oddly enough, all three of these metals have been recovered by mining a single remarkable mineral, carnotite.

continued on page 98



This specimen of high-grade carnotite is typical of material found on mine dumps throughout the Uravan Mining District.

The Uravan Mineral Belt *from page 96*

Compact, handheld, Geiger-type radiation monitors costing as little as $150 can easily detect the radioactivity of uranium minerals.

Carnotite, a hydrous potassium uranium vanadate, is a secondary, or oxidized, uranium mineral. It is brittle and quite soft at Mohs 2. Carnotite crystals are rare; the mineral most often forms powdery coatings, pore fillings, and staining and cementing material on and between sandstone grains. Carnotite's two most important field-identification features are its bright saffron-yellow color and easily detectable radioactivity.

Along with carnotite, other colorful, secondary uranium minerals present in the Uravan include green-yellow autunite, a hydrous calcium uranium phosphate; yellow tyuyamunite, a hydrated calcium uranium vanadate; and green torbernite, a hydrated copper uranium phosphate. Two primary, brownish-black uranium-ore minerals, uraninite, a uranium oxide, and coffinite, a uranium silicate, also occur in the Uravan. Because of their fascinating history, all these uranium minerals make interesting collectibles.

Within the Uravan Mineral Belt are some 900 mines, all of which produced at least some uranium ore. Because carnotite is abundant on the mine dumps, along with lesser amounts of other uranium minerals, the Uravan is a great place to collect and to learn something about radioactive minerals.

The mining history of the Uravan Mineral Belt reflects the story of uranium itself. Uranium is a malleable, silver-gray metal about as dense as gold. With an atomic number of 92, it is the last of the natural elements in the periodic table. It ranks 48th in crustal abundance, making it more common than gold and silver combined. Although it does not occur as a native metal, it is present in some 100 minerals, of which only a few oxides, phosphates, silicates, and vanadates are valuable as ores.

German chemist Martin Klaproth discovered uranium in 1789 when he extracted an oxide of a new element while assaying pitchblende, a massive, botryoidal form of uraninite. When chemists finally isolated metallic uranium in 1841, they named it after the recently discovered planet Uranus. At that time, elemental uranium had no use or value whatever.

In 1896, French chemist Antoine Becquerel, while investigating phosphorescence in uranium minerals, inadvertently left a specimen of the rare mineral zippeite (basic hydrous potassium uranyl sulfate) atop a light-protected, unexposed photographic plate. Discovering later that the plate had somehow become exposed, Becquerel deduced that the uranium in zippeite emitted an unknown form of invisible energy.

That energy, first called "uranium rays" or "Becquerel rays," was natural geophysical, ionizing radiation, a mix of alpha and beta particles and gamma rays, all released by the nuclear transmutation, or "decay," of unstable, heavy elements such as uranium and its isotopes. Upon breaking down, the large uranium nucleus produces an orderly, lengthy "decay chain" of such unstable elements and isotopes as thorium, radium, radon, and polonium. This decay chain eventually ends with the stable form of lead.

In 1897, the Polish-born French chemist Marie Curie, who coined the word "radioactivity," found that all uranium minerals contained trace amounts of the decay-chain element radium. Despite its extreme rarity, radium immediately became the subject of medical and scientific research. When medical researchers learned that the radiation from radium halted the growth of certain cancerous cells, the demand for radium, and thus for uranium ores, soared.

Interest in what would soon be named the Uravan Mineral Belt began in 1898 when a French chemist visiting western Colorado obtained samples of a bright yellow-stained sandstone. Mineralogists identified the yellow mineral as hydrous potassium uranium vanadate and named it carnotite after French engineer and mine inspector Marie-Adolphe Carnot.

Upon learning that extraordinarily valuable radium could be obtained from carnotite, American miners rushed into the Uravan. They discovered many shallow, horizontally configured carnotite deposits that could be easily exploited by simple, single-level, adit-accessed underground mines. By 1900, the carnotite production from dozens of small Uravan mines had made the United States the world's leading radium producer.

Radium is the most valuable and certainly the rarest metal ever mined. During the early 1900s, its price fluctuated from $10,000 per gram to as much as $128,000 per gram ($3.5 million per ounce). By the 1920s, Colorado radium miners had milled more than 100,000 tons of high-grade carnotite ore, from which they recovered just 250 grams—about 9 ounces—of radium.

After 1915, newly discovered high-grade uraninite deposits in the Belgian Congo (now Democratic Republic of Congo) made that African colony the world's leading radium source. Although the importance of radium declined in the Uravan Mineral Belt, the mining of carnotite actually increased, this time for its vanadium content. Vanadium, a silvery-white, very hard metal that improves the elasticity and durability of alloyed steel, had achieved industrial importance when Henry Ford began using vanadium steels in his Model-T automobiles.

By 1920, some 200 small, underground mines in the Uravan were shipping carnotite ore to a half-dozen vanadium mills. One of these mills even recovered vanadium concentrates profitably by simply reprocessing old radium-mill tailings. Vanadium mining in the Uravan would remain an important industry until foreign vanadium mines opened in the 1930s.

By then, geologists understood the origin of the Uravan's sandstone-hosted uranium deposits. When a succession of shallow Jurassic and Cretaceous seas and deltas deposited the sandstone, it contained only normal geochemical traces of uranium. But two factors made the sandstone an excellent trap for uranium mineralization. First, the sandstone's great porosity permitted the passage of huge volumes of mineral-laden water. Second, the sandstone was rich in organic matter, in which carbon acted as a chemical-reducing agent to precipitate uranium compounds into concentrated deposits.

Because uranium salts are very water soluble, they are easily leached from their original host rock and transported in very dilute solutions. Under the right conditions, dissolved uranium will precipitate to form secondary deposits of varying concentrations. In the Colorado portion of the Uravan Mineral Belt, groundwater percolating downward through the porous, carbon-rich sandstone precipitated uranium as concentrated deposits of the secondary mineral carnotite.

Uranium deposition occurred somewhat differently in the Utah section of the Uravan. There, deep hydrothermal

solutions carrying dissolved uranium were transported upward into overlying sandstone strata to precipitate as deposits of the primary mineral uraninite.

In the 1930s, the true value of the Uravan's uranium deposits was just becoming apparent. Physicists were finding that neutron bombardment caused uranium nuclei to fission, or split, into radioactive isotopes of lighter elements, releasing huge amounts of energy. Some researchers theorized that neutron bombardment of a sufficient mass of uranium could release enough other neutrons to create a self-sustaining fission reaction.

In 1942, U.S. researchers constructed an atomic "pile" consisting of 6 tons of uranium metal, 58 tons of uranium oxide, and 400 tons of neutron-deflecting graphite. The resulting continuous fission reaction proved the feasibility of atomic weapons and triggered an emergency effort to obtain large quantities of uranium. Canada and the Belgian Congo provided most of the uranium used in the three historic atomic detonations of 1945. A Uravan mill also contributed by reprocessing vanadium-mill tailings for their uranium content.

With uranium now a strategic material vital to national defense, the newly created Atomic Energy Commission (AEC) set out in 1947 to immediately develop secure, domestic uranium sources by subsidizing a wild rush to the Uravan Mineral Belt. The AEC built eight mills that paid high prices—in cash—for uranium ore, offered bonuses for uranium discoveries, granted mine development allowances and low-interest loans, paid special premiums for high-grade ores, and provided haulage allowances from remote mine sites. Meanwhile, the U.S. Geological Survey collected hundreds of thousands of feet of core samples of Uravan sandstone and publicized its findings, the federal Bureau of Land Management bladed some 1,000 miles of back-country access roads, and the U.S. Bureau of Mines dispensed technical mining assistance free of charge.

Carnotite, which suddenly glittered brighter than gold, lured thousands of amateur and professional prospectors to the Uravan. Although war-surplus jeeps and Geiger counters replaced burros and gold pans, this was the nation's last frontier-style mineral rush—and it was a huge success. By 1952, prospectors had discovered hundreds of carnotite deposits and the 400 small mines in the Colorado section of the Uravan were shipping carnotite ore. The towns of Gateway, Paradox, Bedrock, Naturita, Slick Rock, Uravan, and Vancorum (a corruption of the *Van*adium *Cor*poration of *Am*erica acronym) boomed, while the nearby city

Prospectors discovered many shallow, horizontally configured carnotite deposits that could be easily exploited by single-level underground mines.

of Grand Junction became the region's economic, shipping and trading center.

The Utah section of the Uravan saw relatively little mining action until 1952 when an unemployed oil geologist named Charles Steen prospected the remote Lisbon Valley southeast of Moab. Steen was not looking for shallow carnotite deposits, but for deeper, unoxidized mineralization. He believed that upward-moving uranium-rich hydrothermal solutions could form concentrated deposits in anticline structures similar to those that trap oil. Many laughed at his idea—until Steen's core samples from a depth of 172 feet revealed the largest deposit of high-grade uranium ore ever discovered in the United States.

The ore from Steen's famed Mi Vida Mine, which graded as high as 86 percent uraninite, made him fabulously wealthy. Following Steen's lead, Utah prospectors made a succession of other nearby strikes. Meanwhile, the former farming town of Moab, suddenly the site of a big, new uranium mill, became known as "The Uranium Capital of the World."

Uranium mills such as those in the Uravan produce "yellowcake," a claylike, brownish-yellow paste of insoluble uranates and uranium oxides consisting of the chemical equivalent of 75 percent uranium oxide (U_3O_8). These mills shipped yellowcake in steel drums weighing about 500 pounds each. The potential energy contained in a single drum of yellowcake is equivalent to that contained in 15,500 barrels of fuel oil or 5,000 tons of coal.

But to utilize this energy, yellowcake requires further processing. The natural uranium in both uranium minerals and yellowcake consists of three isotopes:

continued on page 106

nearly 99.3 percent U-238, 0.7 percent U-235, and a trace of U-234. Uranium's value is due almost entirely to U-235, the only fissionable material found in nature. Diffusion plants first convert yellowcake to uranium hexafluoride gas. Then the isotopic gas is densitometrically separated and concentrated by gravitational and membranous methods. The portion high in U-235, called "enriched uranium," is the basic material for manufacturing nuclear weapons and power-plant fuel rods, and for conversion into such transuranic elements as plutonium.

This first Uravan uranium-mining boom peaked in 1957, with 900 mines shipping carnotite and uraninite ores. By then, big open-pit mines in New Mexico and Wyoming were also contributing heavily to domestic uranium production. With its yellowcake warehouses overflowing, the AEC terminated its incentive program. Without price supports, uranium prices plummeted and most mines closed within a year.

The Uravan's fortunes then settled into a repetitive pattern of boom and bust that followed the ups and downs of the uranium market. The bust of the 1960s turned to boom in the 1970s, when yellowcake stocks had finally depleted and an expanding nuclear arsenal and the need for more fuel rods for growing numbers of nuclear power plants spurred uranium demand. With the future of nuclear power looking bright, prospectors and miners now headed back to the Uravan.

But just as many mines were reopening, safety concerns following the accidental radiation release at Pennsylvania's Three Mile Island nuclear power plant in 1979 resulted in the cancellation of contracts for many new nuclear plants. Most mines again shut down in the face of sagging uranium demand.

This time, market oversupply was compounded by the effects of international nuclear disarmament agreements. As thousands of nuclear weapons were dismantled, their weapons-grade (highly enriched) uranium was reprocessed into fuel rods for power generation, virtually eliminating the need for newly mined uranium.

The depressed state of the uranium market didn't begin changing significantly until 2002. By then, yellowcake stocks were low and the weapons-dismantling programs were winding down. Nevertheless, more than 100 domestic nuclear-power plants continued to require fuel rods, while the federal government began pushing for more nuclear energy. Now, with uranium prices at record levels and sure to go higher, the Uravan is gearing up for yet another boom.

This time around, though, mining will be much safer than it was during the 1940s and '50s, when the health hazards of underground uranium mining were poorly understood. By the mid-1950s, many Uravan miners had begun contracting often-fatal lung cancer. Medical researchers soon determined the cause to be the high underground levels of intensively radioactive radon and its deadly "daughter" isotopes.

Radon, a radium-decay product, and its daughters are odorless, tasteless, invisible gases. Unaware of the danger of radon, early uranium miners had compounded their health risks with poor underground ventilation that enabled radon to accumulate to high levels. Many miners also smoked, inhaling smoke particles (which are essentially heat-activated charcoal) that had concentrated radon atoms by adsorbing them from the air. Today, strict no-smoking regulations and mandatory high-volume ventilation systems have eliminated the radon danger in underground mining.

There are some 900 mines within the Uravan Mineral Belt, all of which produced at least some uranium ore.

Today's resurgence of Uravan mining also promises to favorably impact mineral collecting. The supply of once-popular and inexpensive uranium minerals like uraninite, carnotite, tyuyamunite, torbernite, and autunite has been limited since many uranium mines closed 25 years ago. Now, six Colorado mines have already reopened, and 20 more may reopen within two years. As always, more mining will mean greater availability of mineral specimens.

Unlike the uranium fields of Wyoming and New Mexico with their large, corporate mines, the hundreds of small Uravan mines and mine dumps offer easy collecting, mainly for carnotite and sometimes for other secondary uranium minerals. Because of the number of mines, carnotite collecting in the Uravan is not site-specific. The key to successful collecting is to simply plan your trip by studying the appropriate topographical maps showing concentrations of mine sites.

In the Utah section of the Uravan, notably in the Lisbon Valley area, specimens of uraninite and some coffinite (a brownish-black basic uranium silicate) are found on the dumps of the Mi Vida and other deeper mines.

A radiation monitor is indispensable for anyone collecting or prospecting for radioactive minerals. Compact, handheld, Geiger-type radiation monitors costing as little as $150 can easily detect the radioactivity of uranium minerals. These instruments provide relative measurements of specimen radioactivity compared to normal background geophysical and cosmic radiation levels. Radiation monitors are versatile instruments that not only open up new aspects of mineral collecting, but can also detect variations in cosmic radiation (such as those caused by elevation changes or sunspot activity) and potentially dangerous radon concentrations in homes.

The subject of radon warrants a word of warning: When collecting uranium minerals in the field, never enter abandoned, underground uranium mines, most of which have been unventilated for decades. Not only will you face the usual dangers inherent to all old mines, but the underground air may contain radon concentrations thousands of times in excess of the U.S. Environmental Protection Agency's "maximum safe" levels.

When properly handled, uranium minerals do not constitute a health hazard. Because of uranium's slow rate of nuclear decay, its minerals are only mildly radioactive. But for the sake of caution, always store uranium specimens in well-ventilated areas some distance away from offices, bedrooms, or other frequently used rooms. Furthermore, store specimens in containers to prevent loose particles from scattering. Always wash hands after handling uranium minerals, and never allow children to play with specimens.

Only time and the price of uranium will tell how far this mining boom will go. But it has already renewed interest in uranium minerals and is inspiring rockhounds to prowl the Uravan canyons and plateaus with rock picks and radiation monitors.

What are the chances of a rockhound actually making a new uranium strike? Considering the professional competition equipped with state-of-the-art geophysical exploration tools, the chances are not good, but rockhounds won't leave the Uravan Mineral Belt empty-handed. At the least, they will come away with a sense of the history of an unusual mining region and some nice specimens of carnotite, uraninite, and perhaps other uranium minerals.

Aquamarine crystal, Gilgit, Pakistan

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